NASA TECHNICAL NOTE

NASA TN D-4408

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NASA TN D-4408

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MARCH 1968

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SUMMARY

An investigation was conducted in the 41-foot (12.5-meter) vacuum sphere at the Langley Research Center to determine the impingement forces, moments, and centers of pressure on a flat plate produced by small control-type nozzles or jets discharging generally parallel to the plate in a near vacuum. The nozzles tested were conical, had approximately the same throat areas, utilized unheated gas, and had nominal exit Mach numbers of 1, 3, 5, and 7 for air, and 1, 3, and 7 for helium. The ratios of nozzle total pressure to ambient pressure varied from 15×10^6 to about 22×10^6; the ratios of nozzle exit pressure to ambient pressure varied from about 1.4×10^4 to 12×10^6 for the tests at a constant pressure altitude of 95 kilometers. Nozzle positions were varied longitudinally and vertically relative to the plate. Angle of incidence of the flat plate relative to the nozzle center line was varied between -2° and 10° for the air nozzles. The flat plate was detached from the nozzle and mounted on a balance to measure the impingement effects directly.

Significant normal forces and moments were obtained and were found to be dependent on nozzle vertical position, longitudinal position, jet exit Mach number, jet flow turning angle, and angle of incidence of the plate. The largest normal force was equal to about 50 percent of the gross thrust of the Mach number 1 nozzle when located relatively close to the plate. The impingement forces decreased with increasing height or jet Mach number, and decreasing jet turning angle or angle of plate incidence. Helium jets produced lower impingement forces and moments than the corresponding air jets at comparable locations.

INTRODUCTION

Considerable work has been done in the past on determining the effects of jet interference on the performance, stability, and control of aircraft and missiles for atmospheric flight. Recent studies generally have concentrated on interference effects on spacecraft from highly underexpanded jets for atmospheric-exit flight. For the latter flight domain, the atmosphere tends to disappear, the jet interference on the flow field surrounding the body diminishes, and direct impingement of the jet plume on the body becomes the principal source of the interference forces. For control jets firing parallel to a surface, the flow impinging on the surface is very complex and makes analytical solutions difficult and experimental measurements highly desirable. Basic jet impingement investigations were conducted in references 1 to 4 to determine the impingement pressures from jets on flat plates at altitudes of about 50 kilometers. In reference 4, the pressures due to parallel jets impinging on a flat plate were integrated and were found to be significant and large in some cases. Since there were no data available on the magnitude of forces and moments caused by jet impingement for higher altitudes and the domain of space conditions, an experimental investigation was conducted to obtain data on these effects, and also possibly to obtain a better understanding of the impingement phenomenon in a near vacuum.

A flat plate was employed for the impingement surface since current jet control systems generally utilize nozzles which are small and alined nearly parallel to the adjacent surface. The flat plate was separated from the nozzle apparatus and mounted on a three-component balance so that impingement forces and moments could be measured directly. The plate was square and, according to the pressure distributions of reference 1, the relative plate size to nozzle throat area could be considered infinite for some of the nozzle positions of the test. In order to determine the effects of exit Mach number, a series of conical nozzles having nominal exit Mach numbers of 1, 3, 5, and 7 were tested by using air. To show to some extent the effect of gamma variations, conical nozzles with nominal exit Mach numbers of 1, 3, and 7 (designed for a ratio of specific heats of 1.667) also were tested with helium. Since unheated gas jets were employed, the Mach 5 and Mach 7 air nozzles were operating slightly within the theoretical saturated flow regime (ref. 5). The ratios of total pressure to ambient pressure varied from about 15×10^6 to 22×10^6 for the nozzles at a test pressure altitude of approximately 95 km in the 41 foot (12.5 meter) vacuum sphere at the Langley Research Center. In order to keep the initial conditions relatively constant, a short running time of 25 milliseconds was employed for each test. The nozzle positions were varied longitudinally and vertically over the plate in order to obtain impingement forces and moments for plates of different effective dimensions.

SYMBOLS

The axis system, dimension nomenclature, and force relationships are illustrated in figure 1.

A_j	area of nozzle exit
c	normal distance from plate upper surface to moment center of balance
d_j	diameter of nozzle exit
d_t	diameter of nozzle throat
F_X	force on flat plate parallel to surface
F_Z	force on flat plate normal to surface
H	normal distance from plate to center of nozzle exit
L	total length of plate
ΔL	distance along plate between trailing edge and intersection of normal reference line from plate to nozzle exit; physical reference length
ΔL_i	distance along plate between trailing edge and intersection of initial jet turning angle (α_n) ray line; point nominal impingement
M_j	jet exit Mach number
M_b	pitching moment of plate at balance
M_n	pitching moment of plate referred to nozzle exit center line
p_j	nozzle exit static pressure
p_a	ambient pressure in vacuum sphere
p_t	total pressure or chamber pressure of nozzles
r_j	radius of nozzle exit
T_j	gross thrust of nozzle
x_b,z_b	coordinates referred to balance

x_{cp} center-of-pressure location measured from center of nozzle exit

γ_j ratio of specific heats

θ_p flat-plate incidence angle with respect to nozzle center line

θ_n nozzle half-angle

ν_n Prandtl-Meyer expansion angle from sonic velocity to nozzle-exit Mach number

ν_1 Prandtl-Meyer expansion angle from sonic velocity to jet-boundary Mach number

α_n initial jet turning angle measured between nozzle center line and tangent to jet boundary at nozzle lip

APPARATUS

The apparatus consisted of a flat smooth plate, a three-component balance, a dash pot, nozzles, a test stand, and a plenum chamber pressure gage. A schematic diagram and photograph showing the general arrangement of the test apparatus are presented in figures 1 and 2, respectively. The plate surface had a smooth finish and was square with dimensions of 610 cm (24 in.) on each side. Static loadings of the plate (greater than the anticipated maximum loading due to jet impingement) produced no measureable deflections and thus the plate could be considered as rigid for the tests. A small rectangular aluminum block was attached to the geometric center of the bottom of the test-plate structure for mounting the balance. Attached to the test stand was a dash pot, a simple fluid mechanism used to dampen the amplitude of the oscillations induced on the test plate and balance by the jet impingement. This dash pot consisted of a cylinder filled with a special mixture of oils. Immersed in the oil and attached to the leading-edge test plate was a disk which performed the function of a damping agent. (See fig. 2 for dash pot arrangement.) The size of the test plate was made as large as possible within the allowance of the balance specifications. The test plate and dash pot attachment were within the weight tolerance of the balance system.

Each nozzle tested was mounted on a fixed-position stand which was detached from the remaining test setup. The test plate was adjustable relative to the nozzle in both translation and rotation by a remotely controlled test stand. Air from a tank farm pressurized at 8.3×10^6 N/m^2 abs was fed into an accumulator. The air supply from the accumulator to the nozzles located in the center of the 41-foot (12.5-meter) sphere was controlled by means of a pressure regulator and a quick opening valve. This arrangement enabled an accurate control of the chamber pressure to be maintained for each test run. The range of chamber pressures for the different air nozzles varied from 10.3×10^5 N/m^2 to 14.7×10^5 N/m^2 abs. Helium bottles manifolded together and pressurized at 13.8×10^6 N/m^2 abs were fed into the accumulator. The helium flow supply was controlled by means of the pressure regulator and quick opening valve to maintain a constant chamber pressure for the tests using helium gas. The range of chamber pressures for the different helium nozzles varied from 11.0×10^5 N/m^2 to 11.5×10^5 N/m^2 abs.

TESTS AND MEASUREMENTS

The tests were conducted in the 41-foot (12.5-meter) vacuum sphere at the Langley Research Center at an average starting ambient pressure of 0.67 N/m^2 which corresponds to a pressure altitude, based on the U.S. Standard Atmosphere, 1962, of about 95 km. Variations in the starting pressure altitude of about ±1 km were obtained. The ratios of total pressure to ambient pressure varied from 15×10^6 to 22×10^6 and the ratios of jet exit pressure to ambient pressure varied from 1.4×10^4 to 12×10^6 for the different nozzles tested. In the beginning, several exploratory tests were made to investigate lag, vibrations of the apparatus due to valve operation and jet impact, balance calibration and attenuation checks for low and high loads, dash pot oil consistency, operation of the remote-controlled test stand in the vacuum, radiant temperature variations in the sphere between day and night operation, effect of jet to ambient pressure ratio, and data-reduction problems. All these problems and their effects on the overall repeatability were essentially minimized.

The balance measured normal force and pitching moment. A sample oscillograph record is presented in figure 3 to show the traces of the normal force, pitching moment, and chamber pressures for a typical test run. The running time for each test was about 25 milliseconds. The data point read was a faired value on the oscillographic trace over a 5-millisecond interval preceding gas supply cutoff, as shown in figure 3. Calculations of the ambient pressure during the relative short run time, based on the limiting velocity of the jet and vacuum sphere size, showed that the local pressure altitude of about 95 km would not change during this test interval. In general, the measurement accuracy was estimated to be within ±2 percent of the full-scale ranges of the quantities measured by the balance and ±10 percent for the starting ambient pressure.

Air jet tests were conducted with the use of dry air and conical nozzles designed to have nominal (isentropic) jet or exit Mach numbers of 1, 3, 5, and 7. All the nozzles tested were conical, had sharp lips, and had approximately the same throat area. The nozzle exit areas were determined from isentropic flow relations to obtain the desired Mach numbers. In order to keep the induced or impingement loads on the plate within the calibrated operating range of the balance, the chamber pressures were adjusted to keep the thrust nearly constant for the systematic runs. Gross thrust levels varied somewhat from 14.2 N (3.19 lb) to 14.9 N (3.34 lb) on successive series of runs. For the impingement test program with nozzle center line parallel to the plate, 19 longitudinal positions at increments of 2.54 cm were tested at each of six vertical positions (increments of 2.54 cm). Since the longitudinal travel of the plate was limited, the test series were arranged in overlapping groups of stations. Consistency of test data made it possible to reduce the test points for later runs. The minimum vertical nozzle displacement was determined by the size of either the outside diameter of the plenum chamber or the diameter of the nozzle exit, whichever was larger. Impingement effects were determined for plate angles of attack of -2°, 0°, 2°, 5°, and 10° (see fig. 1) relative to the jet.

Conical nozzles were designed for helium to have nominal exit Mach numbers of 1, 3, and 7. Only jets parallel to the plate $\left(\theta_p = 0\right)$ and for about half of the positions used for these air tests were investigated. Jet thrusts again were maintained at a constant level to be within the range set for the air tests. The stagnation or chamber temperatures for both gases tested were approximately 280° K.

The characteristics of all the nozzles tested are summarized in figure 1(b). Both the nominal and one-dimensional theoretical Mach numbers, based on measured throat and exit diameters, are listed in the figure. According to reference 6, the Mach 5 and 7 air nozzles, which were operating under saturation temperature and pressures, may have had a 10-percent reduction in exit Mach numbers due to condensation effects or two-phase flow.

RESULTS AND DISCUSSION

Basic Data

All force data were nondimensionalized by dividing the measured force by the computed gross thrust of each nozzle. Only the normal-force data are presented since the axial-force data were somewhat erratic and appeared equal to or less than 5 percent of the corresponding thrust. The moment data were transferred from the balance to the center of the nozzle exit since this point was a common reference point for all nozzle interference studies. The moment was nondimensionalized by the product of computed gross thrust and the normal distance to the plate. The center-of-pressure ratio x_{cp}/H was measured from the nozzle exit parallel to the plate as is shown in figure 1(a). Relationships used for computations are compiled in the appendix.

Since the ambient pressures for these tests were lower than those of earlier tests in the facility (refs. 1 and 4), impingement tests were made to determine the effect of altitude variations on the forces and moments on the plate. These tests were made because calculations of the initial jet turning angle at the lip of each nozzle, given in figure 4, show that significant variations of α_n can be obtained at the higher values of p_j/p_a or altitude. These variations, in turn, would affect the amount of plate wetted area. Since the jet flow field along the plate was complex, and in order to simplify the work, it was decided to estimate the wetted area effect by approximating the wetted length on the plate in the plane of the jet. A sketch of this complex flow field made from the schlieren photographs of reference 1 is shown in figure 1(c). The impingement point was estimated by extending the initial turning angle of the streamline at the nozzle lip to the plate. The length from this point to the trailing edge of the plate ΔL_i was the impingement length or the approximate wetted length. Force and moment data were obtained for the air and helium nozzles over the range of altitude pressures from sea level to 99 kilometers for one location. The results are presented in figure 5 for a physical length ratio $\Delta L/L$ of 0.75 and a vertical height ratio H/d_t of 16. In general, the forces and moments decreased with increasing ambient pressure and appeared to become insignificant at low altitudes. At the test altitude the results due to altitude effect varied small amounts and indicated that the tests were in a near-vacuum environment. The results also indicated that the magnitude of the impingement effects would be slightly higher in space. For the following part of the discussion, the air nozzle results are presented first since their tests were more extensive and covered more variables than the helium tests.

Air Nozzle Tests

Effect of nozzle locations.- All the air jet data for the normal-force ratio F_Z/T_j, moment ratio M_n/T_jH, and center-of-pressure ratio x_{cp}/H at zero plate incidence $\theta_p = 0$ are presented in figure 6. The longitudinal location of each test point is defined by the ratio of physical length to plate length $\Delta L/L$ along the abscissa. Each different symbol represents a constant vertical displacement ratio H/d_t. The impingement forces and moments increased as the reference or physical plate length increased. This result was not surprising since the plate wetted area also increased. The magnitudes of the forces obtained varied from a value equal to about 50 percent of the thrust of the Mach 1 nozzle (fig. 6(a)) close to the plate to about 1 percent for the Mach 7 nozzle relatively far from the plate (fig. 6(d)). Increasing the jet Mach number reduced the initial turning angle and produced marked decreases in the impingement normal force and moments. The comparisons also show that the nondimensionalized moments were larger for the low heights and approached values of -2 at $\Delta L/L$ of 1.0. The center-of-pressure ratios varied similarly to the moment ratios.

Since the normal (vertical) displacement also changed the wetted length ΔL_i, it was felt that the wetted length should be held constant in order to isolate the effects of H. The effects obtained for an approximate wetted length of 75 percent of the plate (as determined from the approximate impingement point) and displacement of nozzles vertically along their respective ray lines (α_n values) are given in figure 7. The points shown were obtained from the faired curves in figure 6 at values of reference length $\Delta L/L$ corresponding to the constant wetted length $\Delta L_i/L$. The force parameter decreased with increasing height and decreased with increasing nozzle jet exit Mach number. The magnitude of the nondimensional moment correlated along a single curve which decreased with increasing height. The centers of pressure moved downstream as H/d_t was increased.

The force and moment parameters are summarized as a function of the length-height ratios in figure 8. The variations, in figure 8, with reference length ratio $\Delta L/L$ and with the approximate wetted length ratio $\Delta L_i/H$ were similar; however, the data appeared to correlate better with the latter ratio. Mach number effects appeared to be interpolatable; however, it should be recalled that the Mach 5 and 7 nozzles may have experienced two-phase flow and about 10-percent reduction (ref. 6) in their exit Mach numbers. The scatter in data shown in these summary figures was largely due to experimental and data readout errors.

Effect of jet turning angle.- Because there were a large number of variables to consider, the measured impingement parameters are plotted against jet turning angle α_n for $\Delta L_i/L$ of 0.75 in figure 9. The turning angle depends upon nozzle exit angle, exit Mach number, ratio of specific heats, and ambient pressure. These variables yield an ideal or isentropic expansion angle with no corrections for any condensation effects or nozzle losses. As in the previous case, the variations of the impingement parameters with α_n were smooth, nonlinear, and decreased with increasing nozzle height. It should be remembered that only sharp-lip conical nozzles were investigated and used for the computations of α_n.

Effect of plate incidence.- Angle-of-incidence effects of the plate were measured by mounting each nozzle along the normal line at $\Delta L/L$ of 0.75 and then rotating the plate and balance about a small arc in order to maintain the same normal-to-plate nozzle heights H. The results for the Mach number 1.0, 3.0, and 5.0 air nozzles are presented in figures 10(a), 10(b), and 10(c), respectively. The plate angle of attack θ_p was varied from -2^o to 10^o relative to the jet center line. (See fig. 1(a).) The impingement forces for all nozzles increased significantly at positive plate incidences; for example, at $M_j = 1$ and H/d_t of 8, F_Z/T_j increased from 0.48 at $\theta_p = 0^o$ to 0.62 at $\theta_p = 10^o$ or about 30 percent. The $M_j = 5$ nozzle produced a corresponding increase in force ratio of about 50 percent. The center-of-pressure ratios for each case remained essentially constant with plate angle.

Helium Nozzle Tests

All the helium jet test results were at zero plate incidence. The variations of nondimensionalized normal force, moment, and center of pressure with length, height, length-height ratios, and jet turning angles are presented in figures 11 to 14. A comparison of these results with the corresponding air jet tests in figures 6 to 9 show that a significant reduction in the magnitude of the impingement effects is obtained by changing from air to helium at the same location and for the same nominal nozzle. As an example, at a nozzle height of $16H/d_t$ and a constant plate impingement point or at 0.75L (figs. 8(b) and 13(b)), the Mach 3.0 helium jet reduced the values of F_Z/T_j and M_n/T_jH by about 25 percent and 20 percent, respectively. Since the height, impingement point, nozzle shape, and jet exit Mach number compared are the same for helium and air, it appears that the differences in the impingement effects are largely due to the different jet turning angles.

SUMMARY OF RESULTS

An investigation was conducted in the 41-foot (12.5-meter) vacuum sphere at the Langley Research Center to determine the flat-plate forces, moments, and centers of pressure caused by jet impingement from jets discharging generally parallel to a flat plate in a near vacuum. All the nozzles tested were conical, utilized cold jets, and consisted of nominal Mach number 1, 3, 5, and 7 air jets and Mach number 1, 3, and 7 helium jets. The locations of the nozzles were varied relative to the flat plate, and the following results were observed:

1. Significant normal-force and moment effects were found to exist. The magnitude of these effects was found to depend upon vertical position, longitudinal position, jet exit Mach number, jet flow turning angle, and flat-plate angle of incidence.

2. The magnitude of nondimensionalized normal-force and moment parameters was decreased by increasing nozzle height or jet exit Mach number; and, by decreasing effective plate length, jet exit turning angle, or angle of incidence of the plate.

3. For air jets, the largest normal force measured was equal to about 50 percent of the gross thrust for the Mach number 1.0 nozzle located relatively close to the plate, and the corresponding moments were nearly twice that of the moment about the plate due to the isolated thrust. The lowest force was from the Mach number 7 nozzle located at the highest test position above the plate.

4. All normal forces and moments from the helium jets were lower than those for air at comparable nozzle locations and the same nominal Mach number nozzles.

5. Decreasing pressure altitude or increasing ambient pressure in the vacuum sphere reduced the magnitude of the impingement parameters.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., November 14, 1967,
125-19-03-10-23.

APPENDIX

DATA ANALYSIS EQUATIONS

The relationships used for the analysis of the basic data measurements are summarized as follows:

Nozzle gross thrust:

$$T_j = p_j A_j \left(1 + \gamma_j M_j^2\right) - p_a A_j \tag{A1}$$

Jet exit static pressure:

$$p_j = p_t \left(1 + \frac{\gamma_j - 1}{2} M_j^2\right)^{\frac{\gamma_j}{\gamma_j - 1}} \tag{A2}$$

Moment transferred to nozzle exit center line:

$$M_n = M_b - F_Z x_b + F_X z_b \tag{A3}$$

Center of pressure:

$$x_{cp} = \frac{M_n}{\sqrt{F_Z^2 + F_X^2}} \tag{A4}$$

Jet exit flow turning angle:

$$\alpha_n = \nu_1 - \nu_n + \theta_n \tag{A5}$$

Prandtl-Meyer expansion angle:

$$\nu = \cos^{-1} \frac{1}{M_j} - \sqrt{\frac{\gamma_j + 1}{\gamma_j - 1}} \tan^{-1} \sqrt{\frac{\gamma_j - 1}{\gamma_j + 1}\left(M_j^2 - 1\right)} \tag{A6}$$

Transfer of longitudinal coordinates:

$$\frac{\Delta L}{L} = \frac{\Delta L_i}{L} + \frac{(H + c) - r_j}{L \tan \alpha_n} \tag{A7}$$

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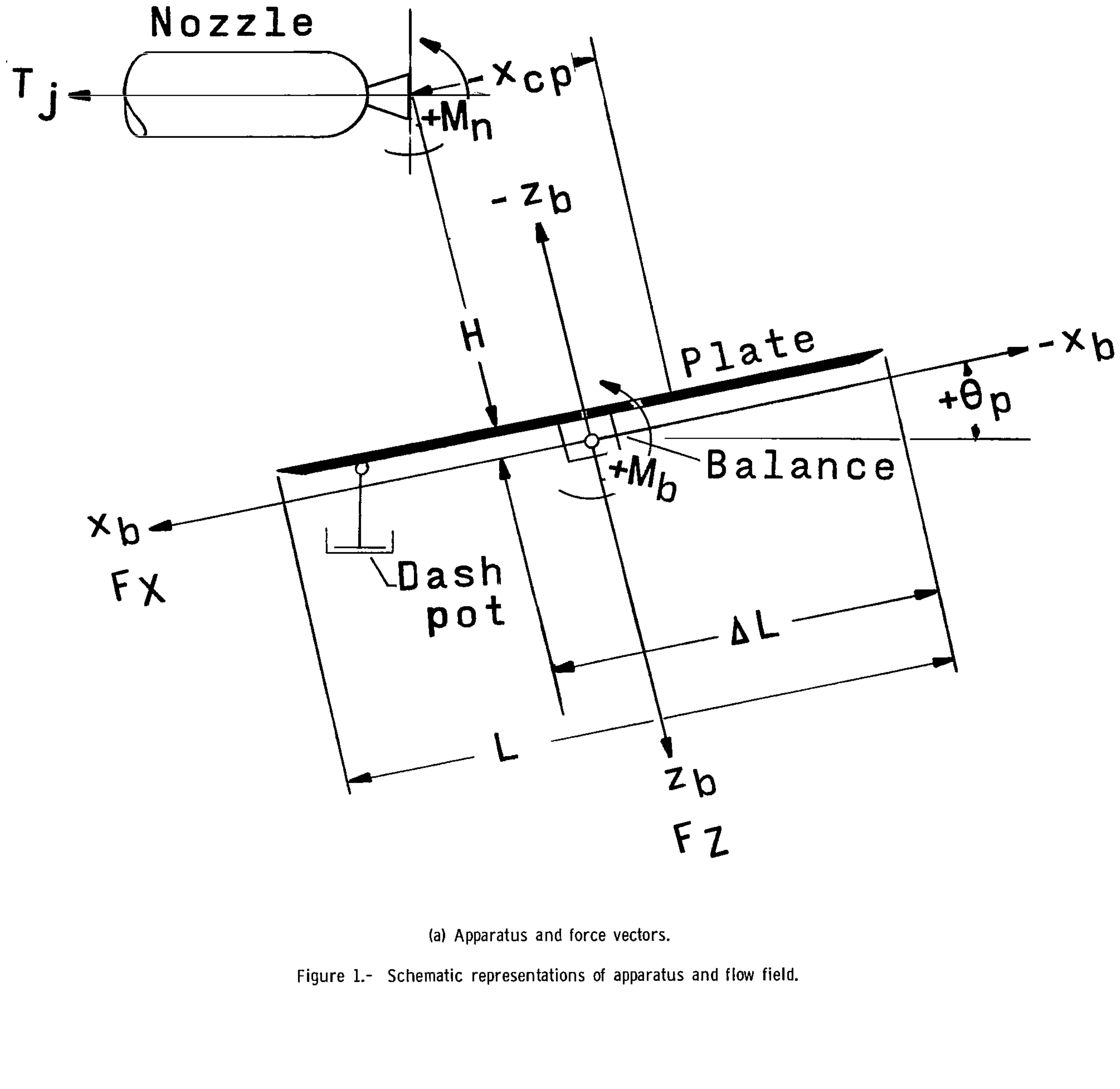
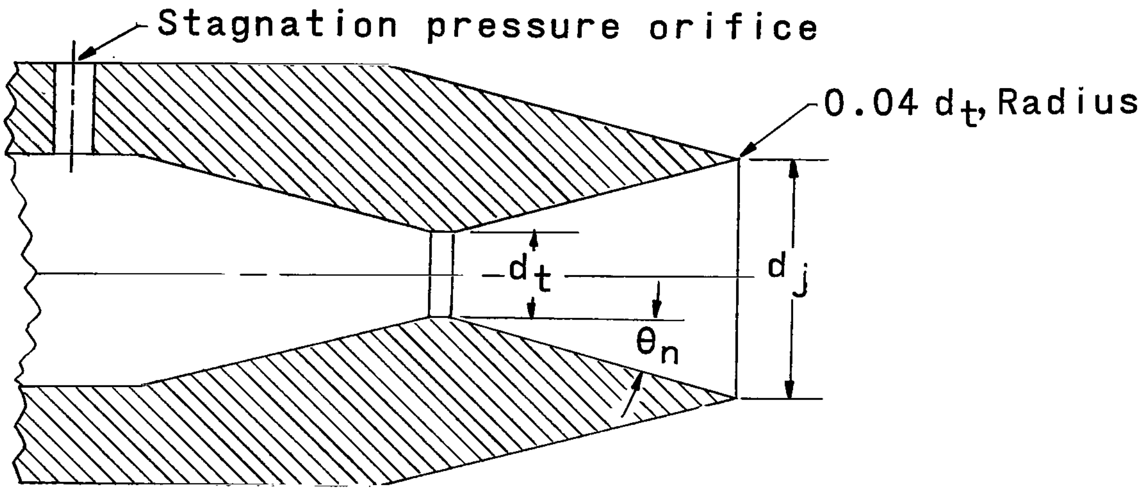


(a) Apparatus and force vectors.

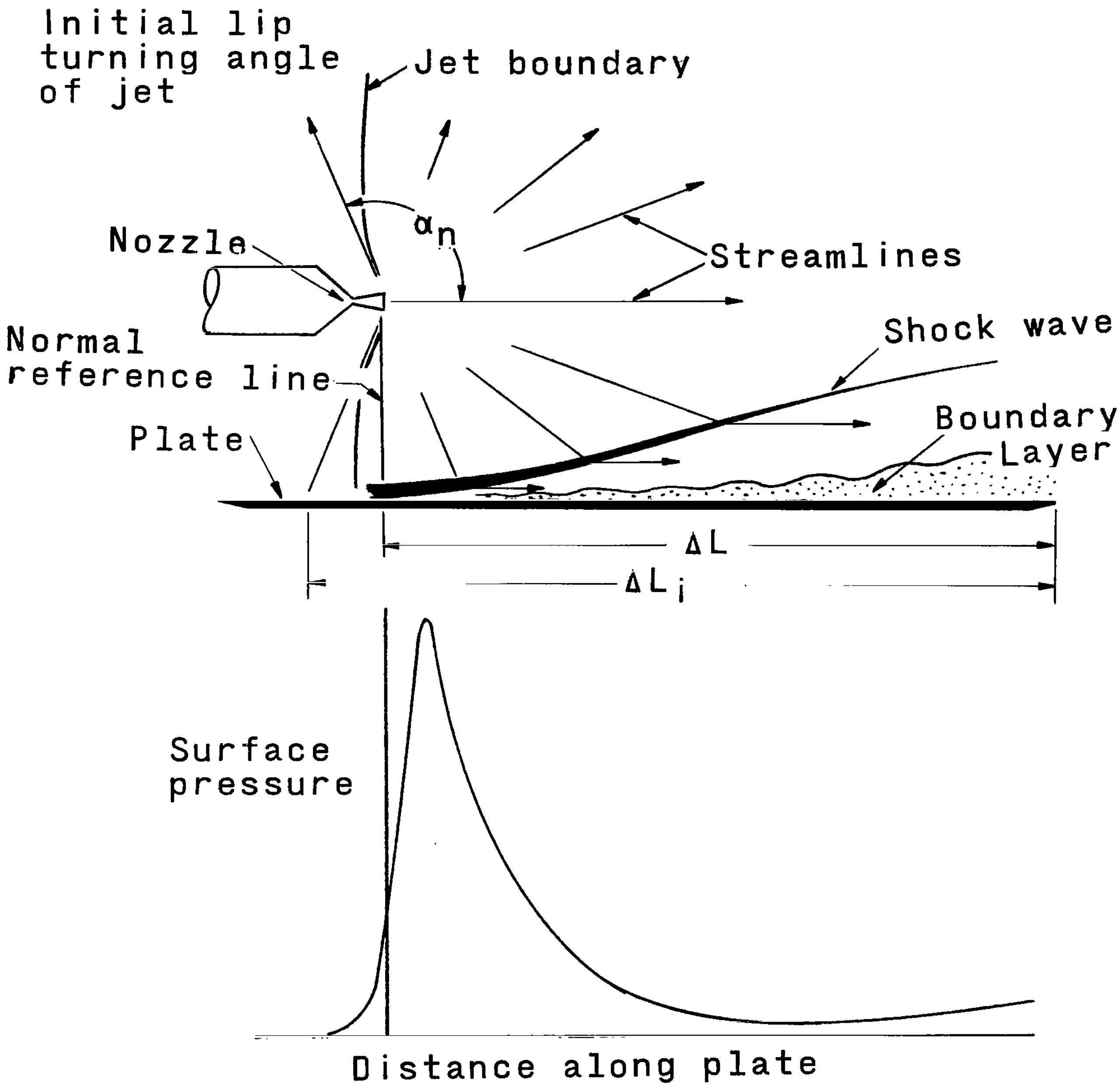
Figure 1.- Schematic representations of apparatus and flow field.



M_j, nominal	M_j, theoretical	d_t, cm	d_j, cm	θ_n, deg	γ_j	$\frac{p_j}{p_a}$
			Air			
1	1	0.318	0.318	0	1.40	1.2×10^7
3	2.96	.318	.640	15	1.40	4.9×10^6
5	4.92	.327	1.588	15	1.40	3.2×10^5
7	6.95	.320	3.213	18.3	1.40	3.9×10^4
			Helium			
1	1	0.318	0.318	0	1.667	1.0×10^7
3	2.97	.320	.554	15	1.667	3.5×10^5
7	6.93	.327	1.588	15	1.667	1.4×10^4

(b) Nozzle characteristics.

Figure 1.- Continued.



(c) Schematic flow field and plate pressures.

Figure 1.- Concluded.

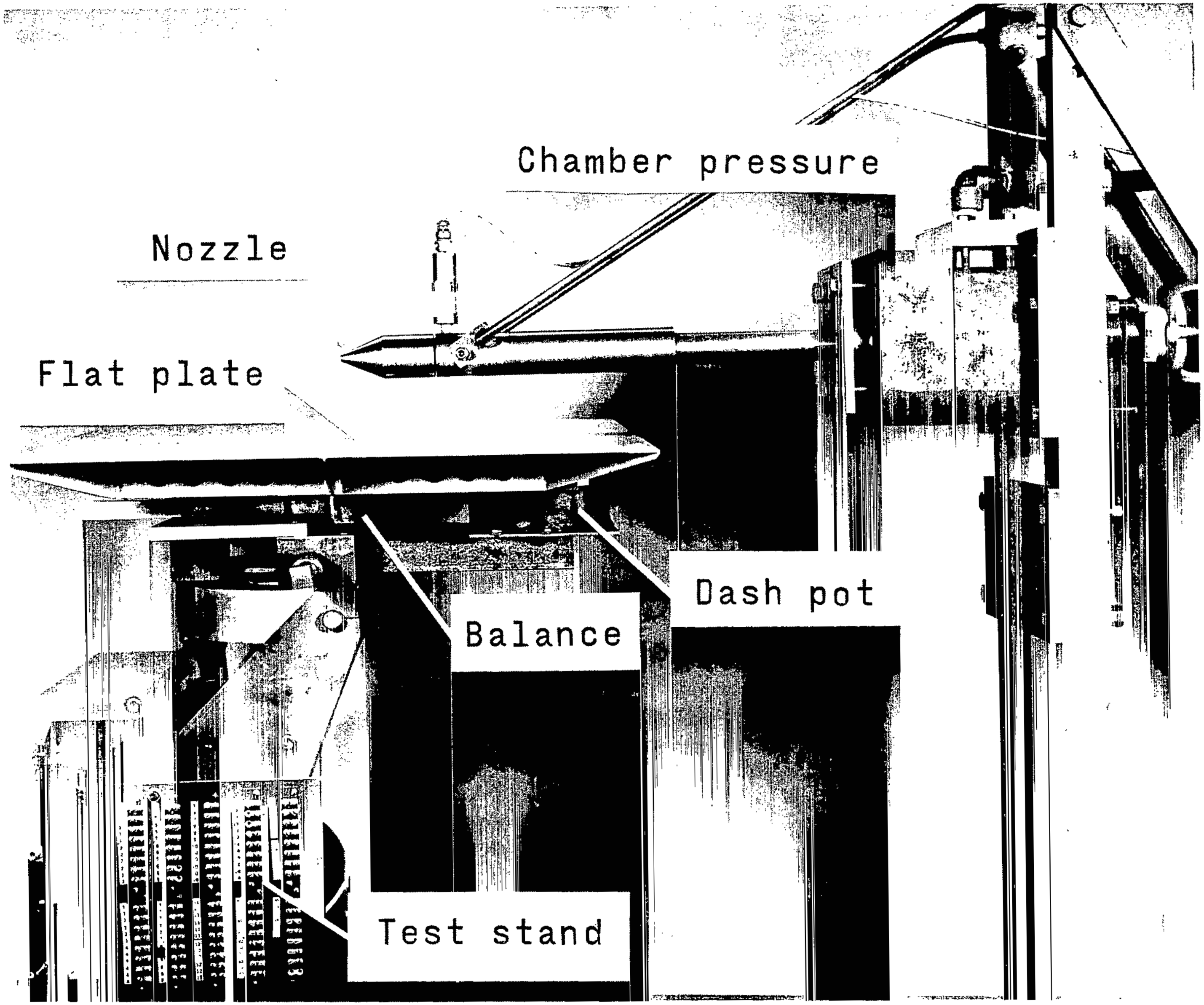


Figure 2.- Photograph of apparatus. L-67-6446

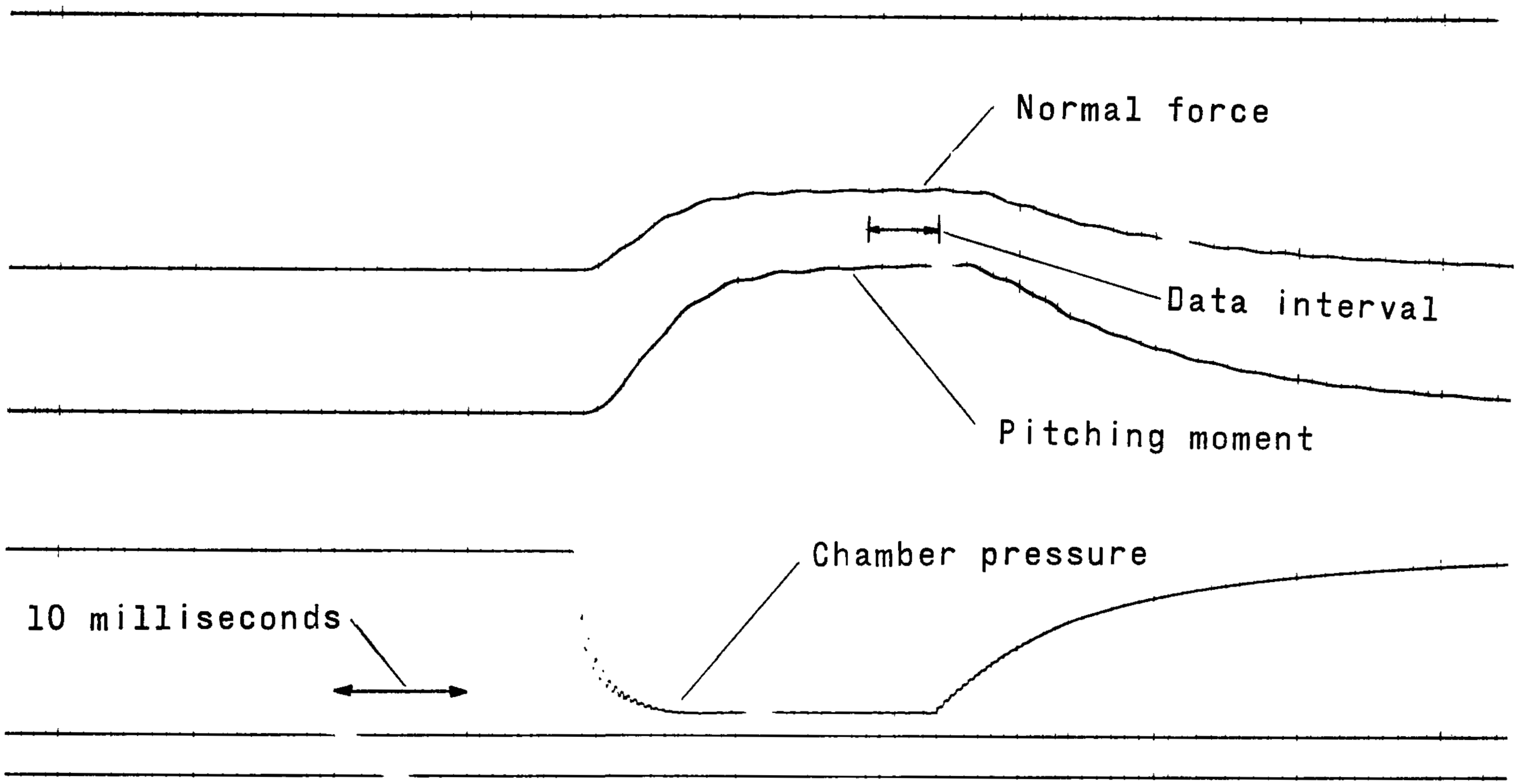


Figure 3.- Typical oscillograph record. Test at Mach number 3, $\Delta L/L = 1.0$, and $H/d_t = 16$.

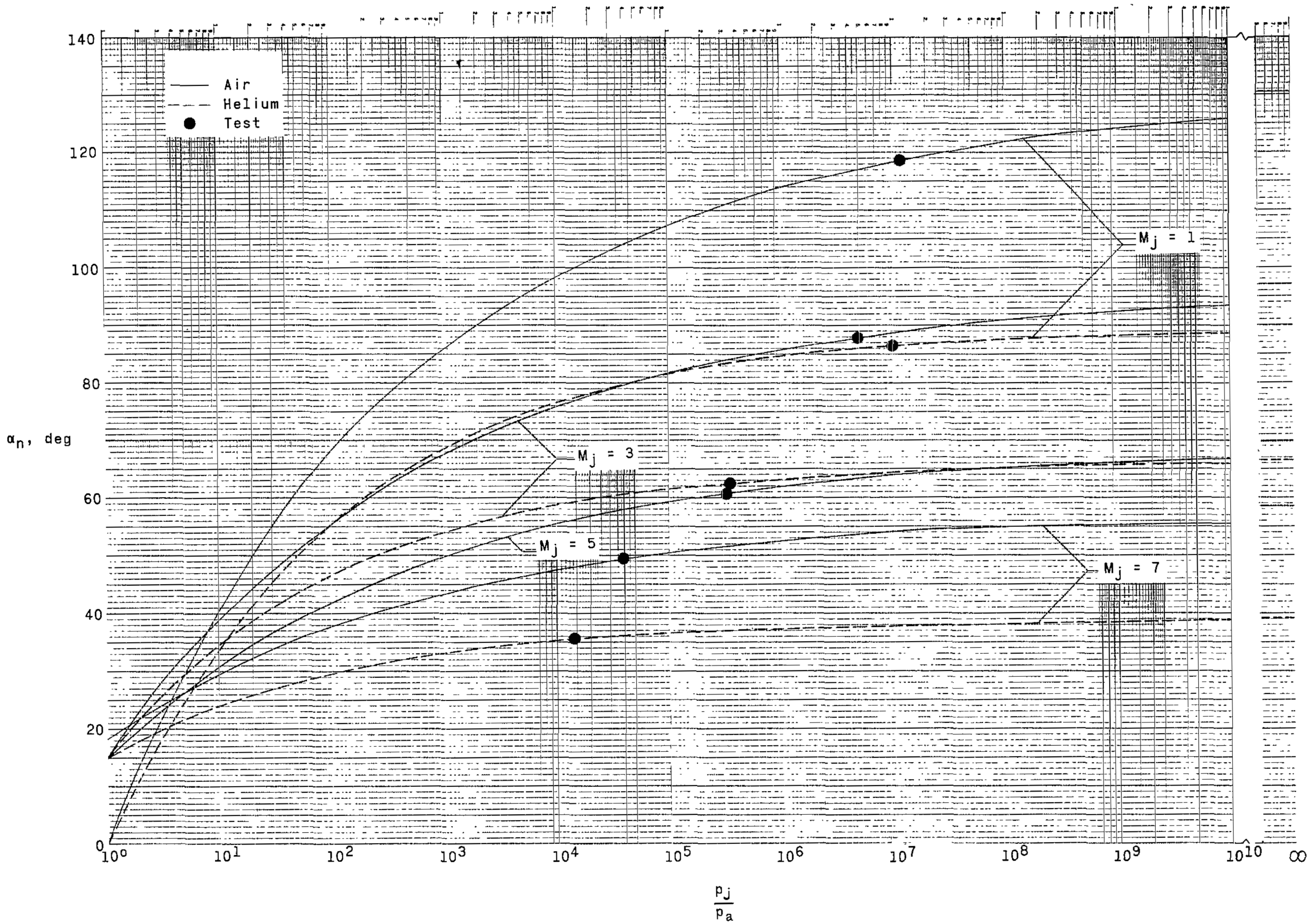


Figure 4.- Variation of initial turning angle with jet exit to ambient pressure ratio for air and helium nozzles.

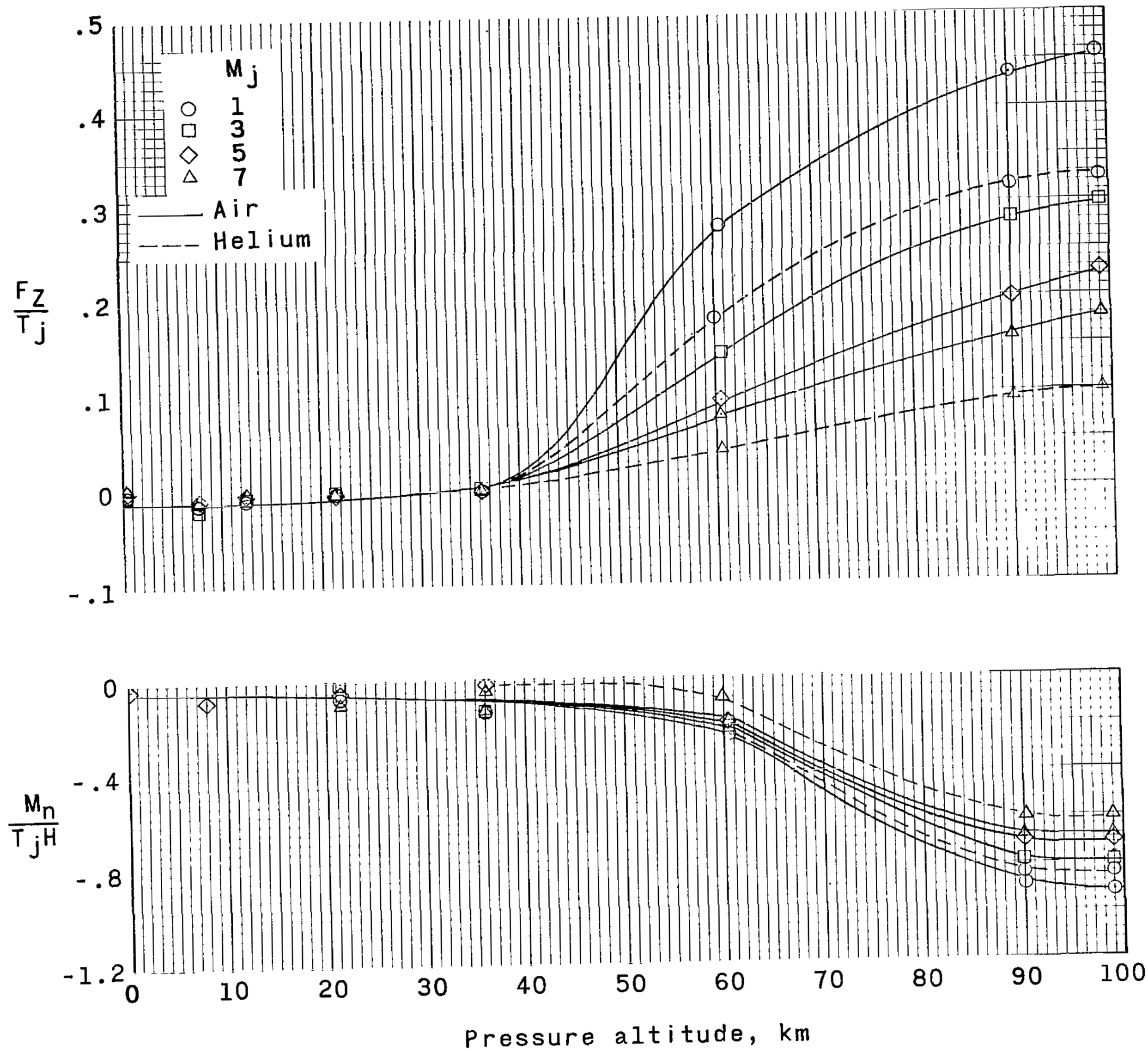
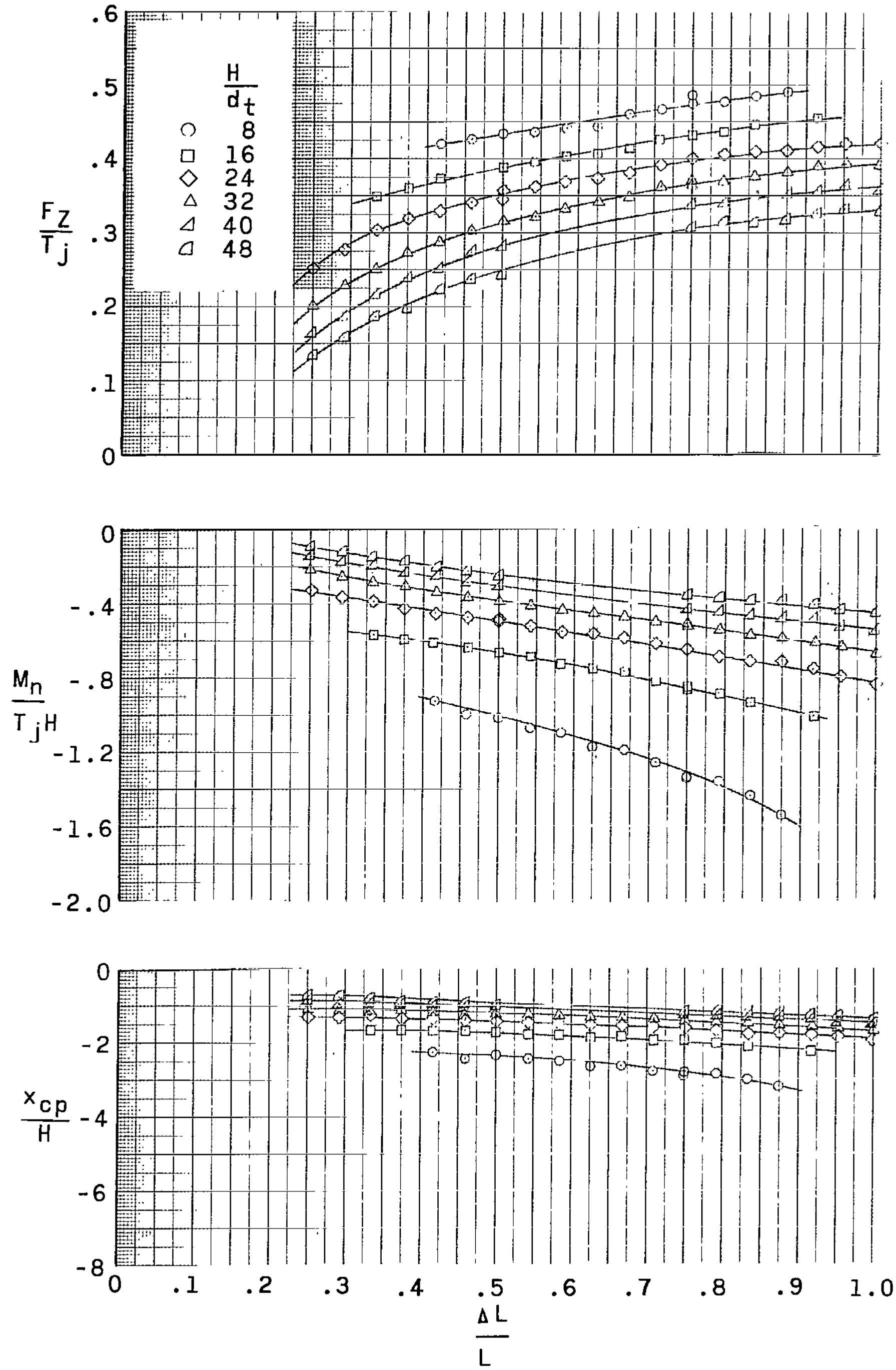
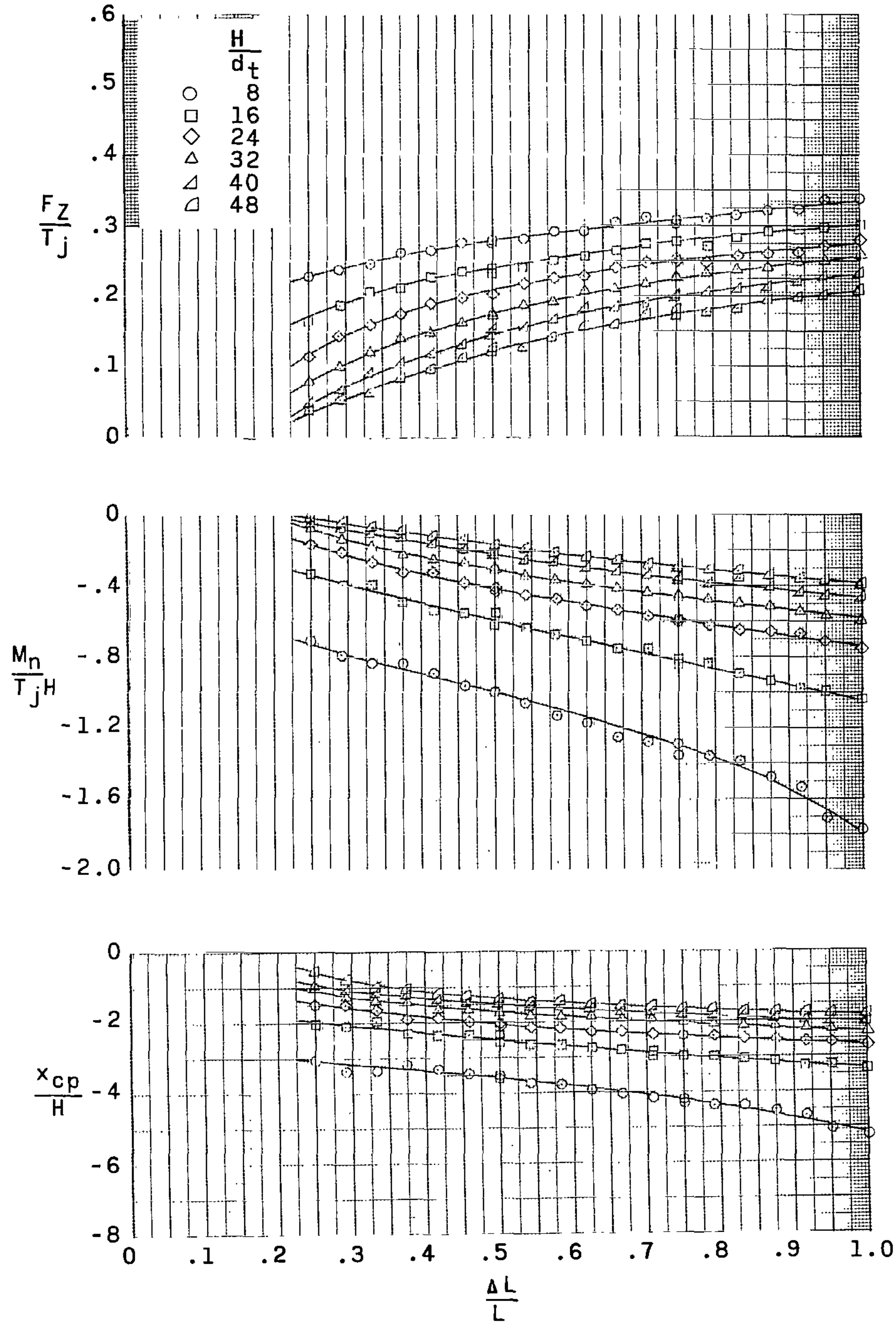


Figure 5.- Variations of normal-force and moment parameters for several nozzles with ambient pressure or altitude. Constant nozzle position at $\Delta L/L = 0.75$ and $H/d_t = 16$.



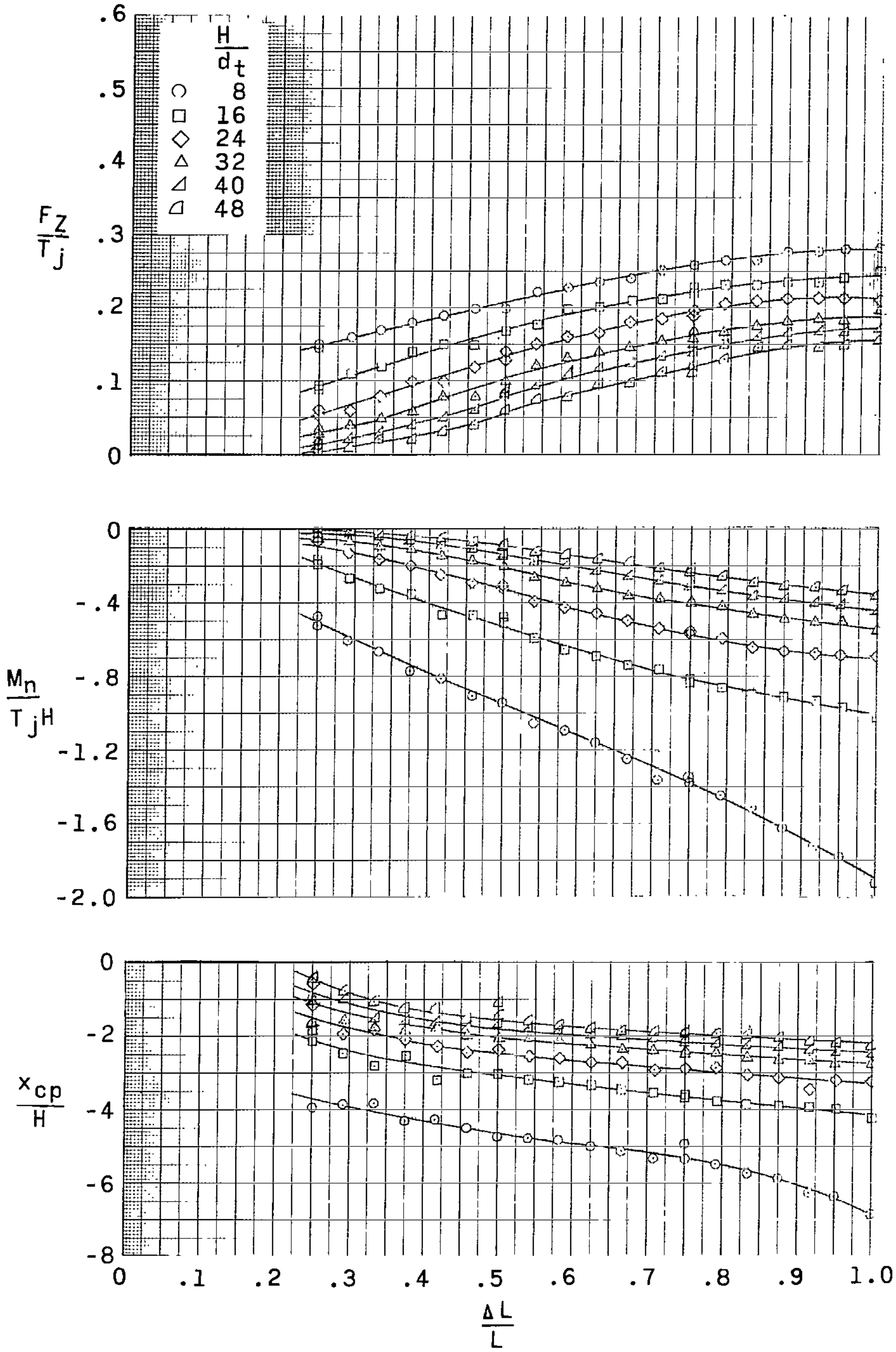
(a) Mach number 1.0 nozzle; air.

Figure 6.- Variations of normal-force, moment, and center-of-pressure parameters at various vertical displacements of the nozzles with longitudinal position.



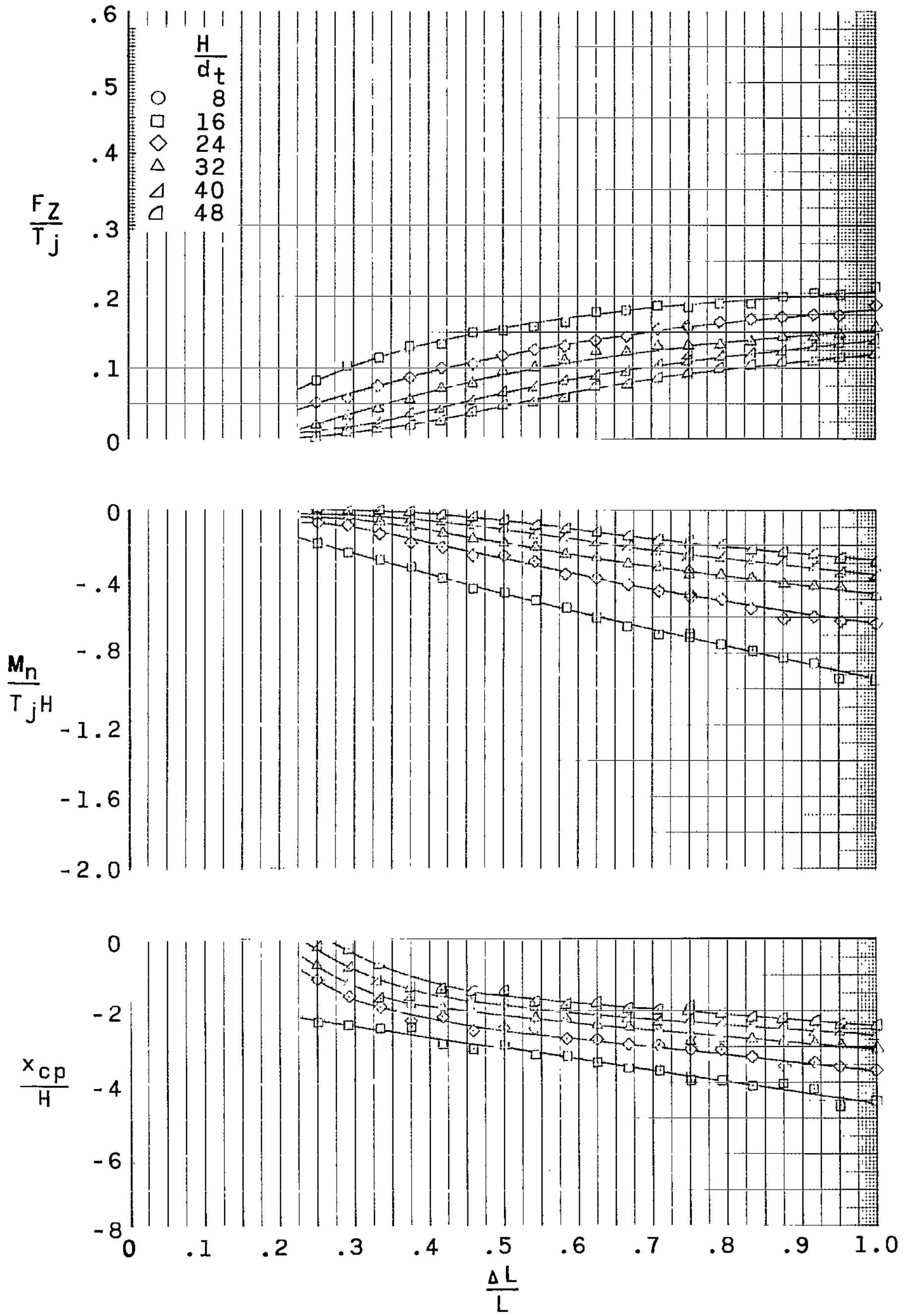
(b) Mach number 3.0 nozzle; air.

Figure 6.- Continued.



(c) Mach number 5.0 nozzle; air.

Figure 6.- Continued.



(d) Mach number 7.0 nozzle; air.

Figure 6.- Concluded.

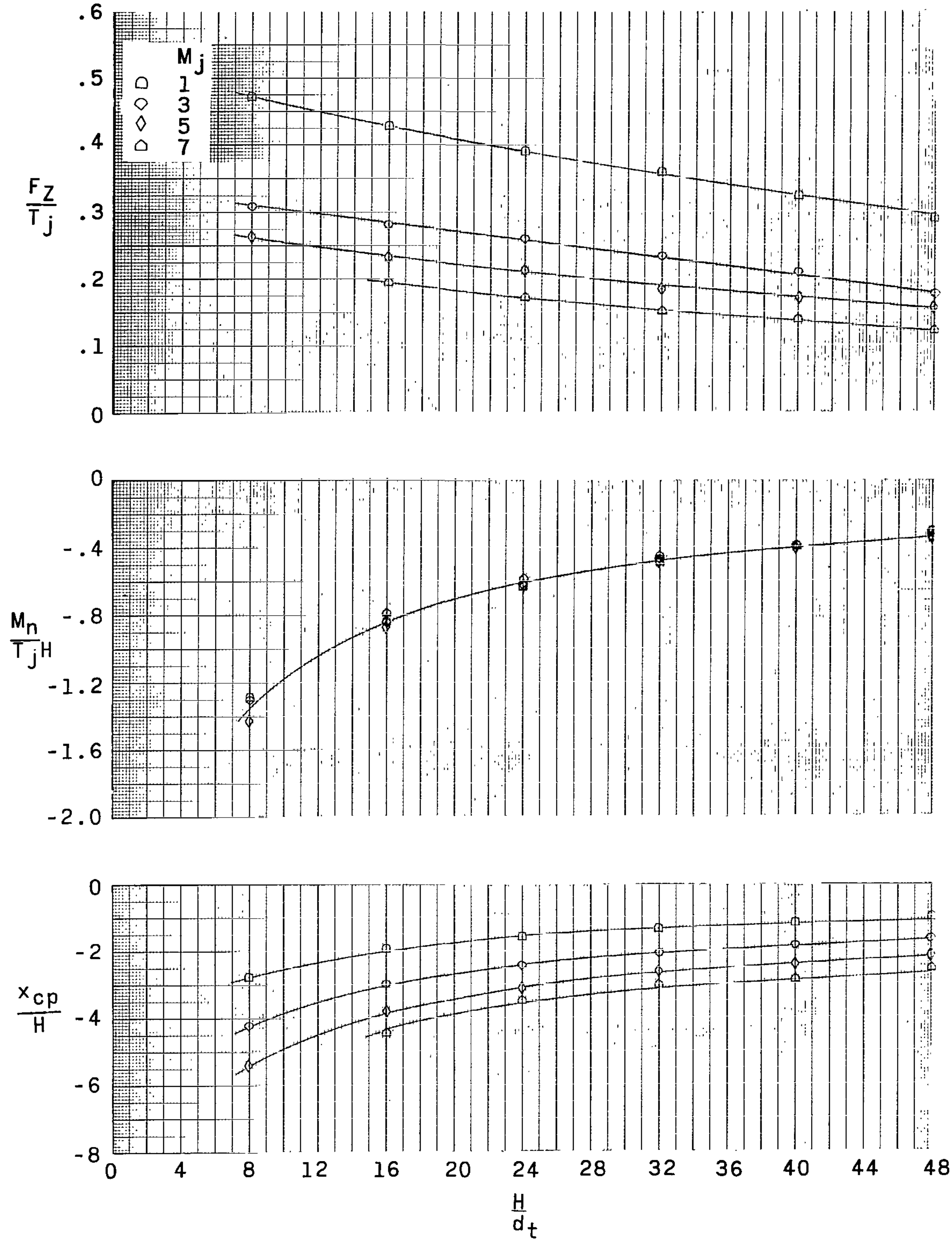
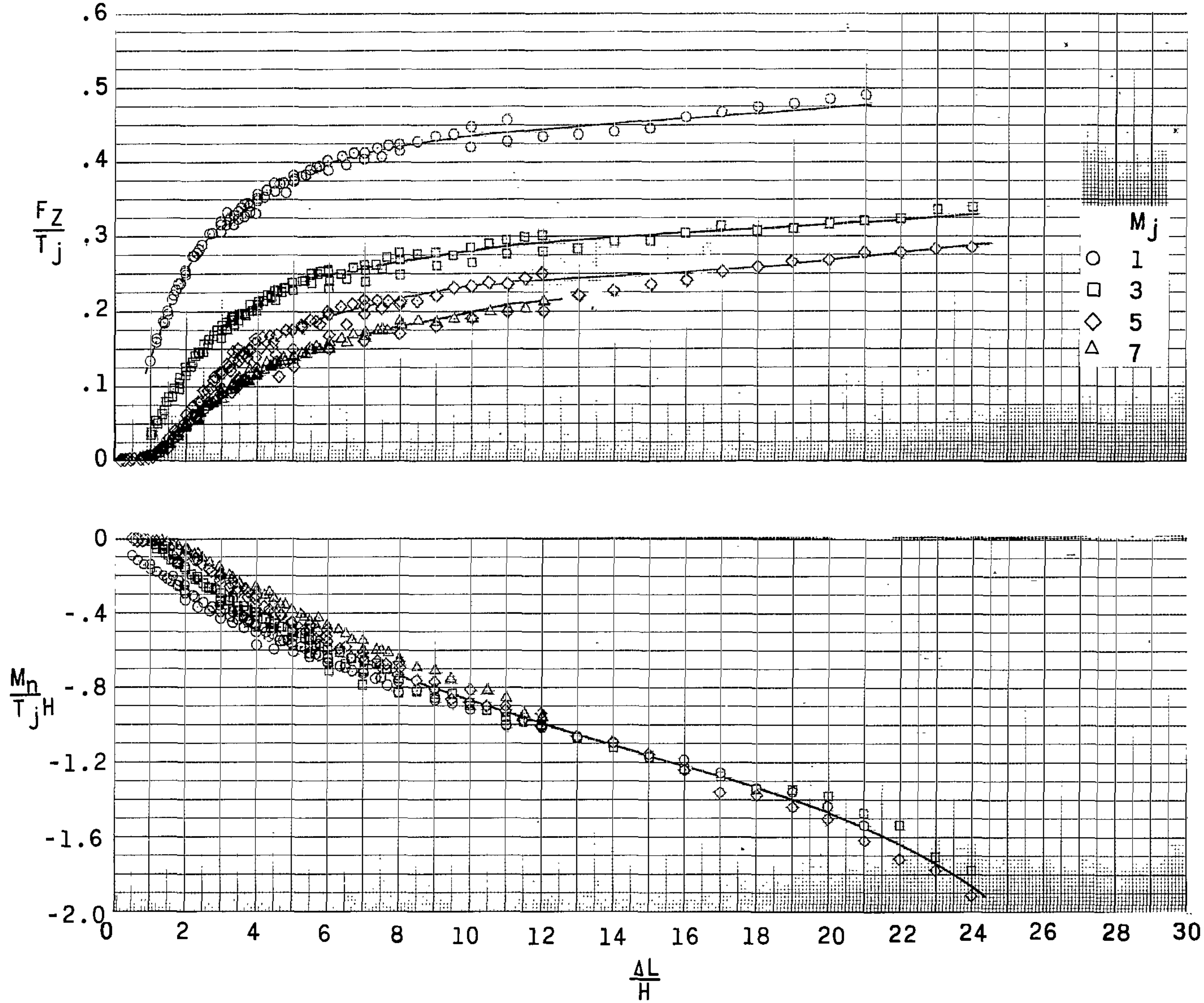
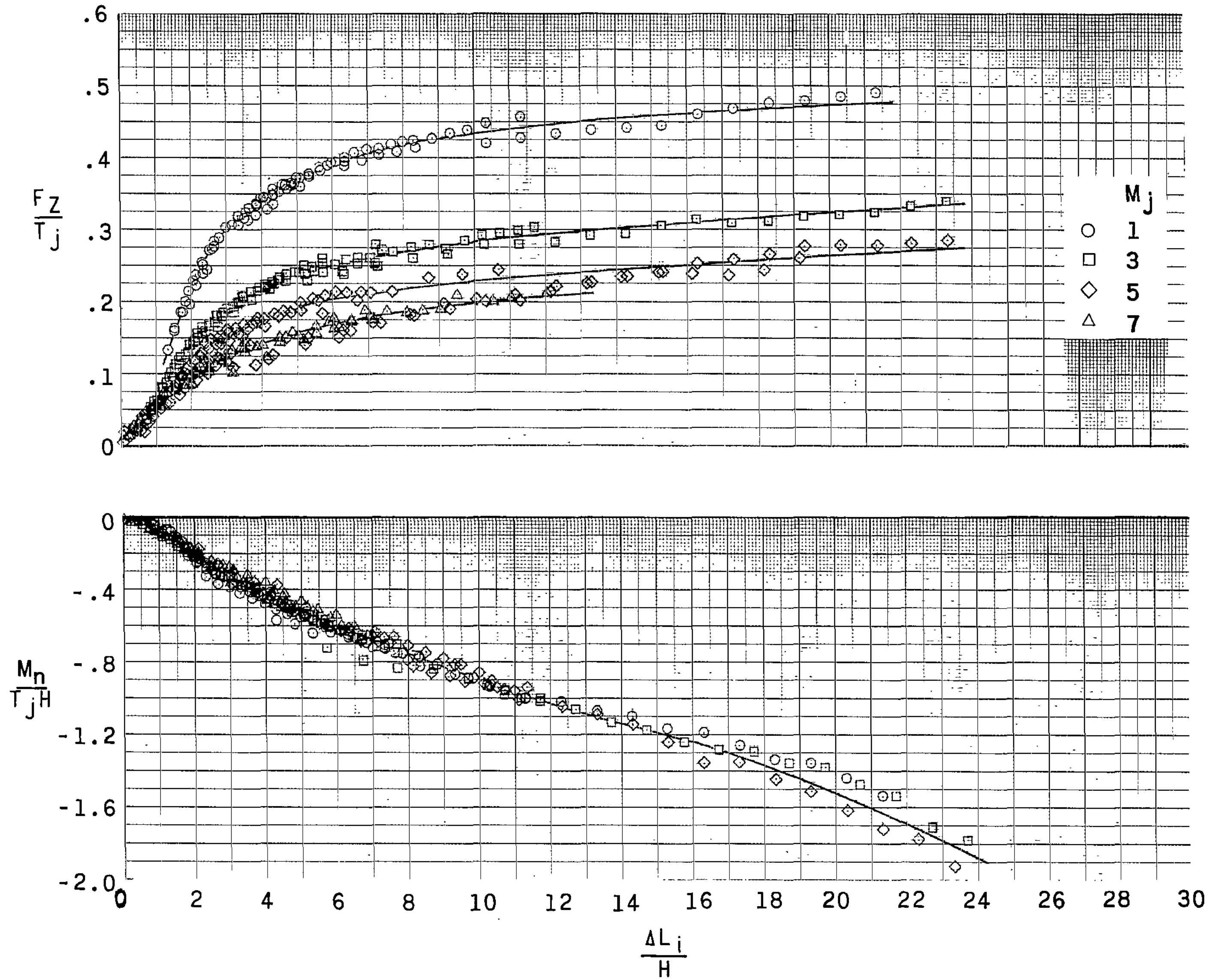


Figure 7.- Variations of normal-force, moment, and center-of-pressure parameters for the air nozzles with vertical position at $\Delta L_j/L = 0.75$. Symbols are for identification only.



(a) Positions normal to plate; air.

Figure 8.- Variations of normal-force and moment parameters for the air nozzles with ratio of longitudinal position to vertical displacement.



(b) Positions at nominal jet-impingement points; air.

Figure 8.- Concluded.

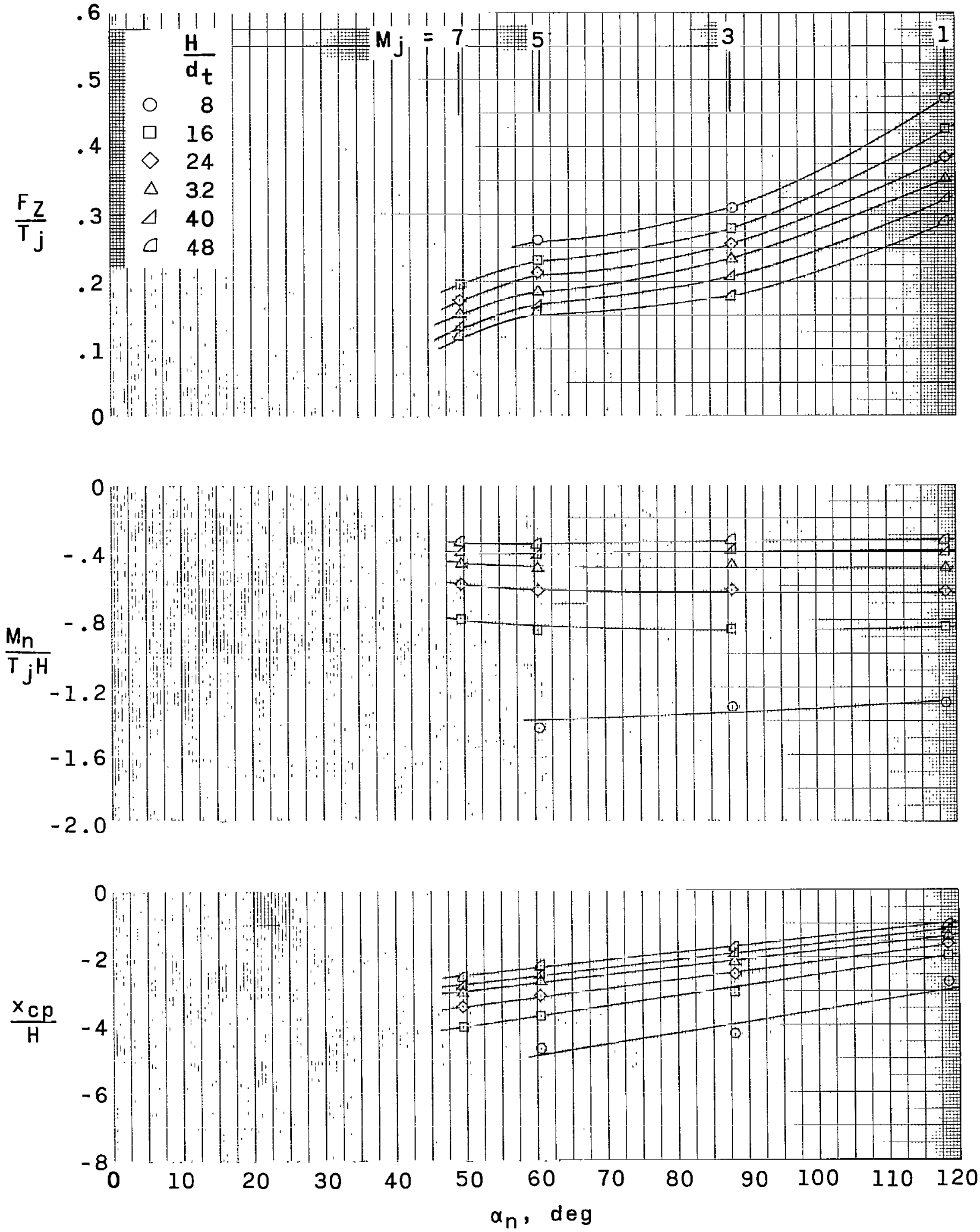
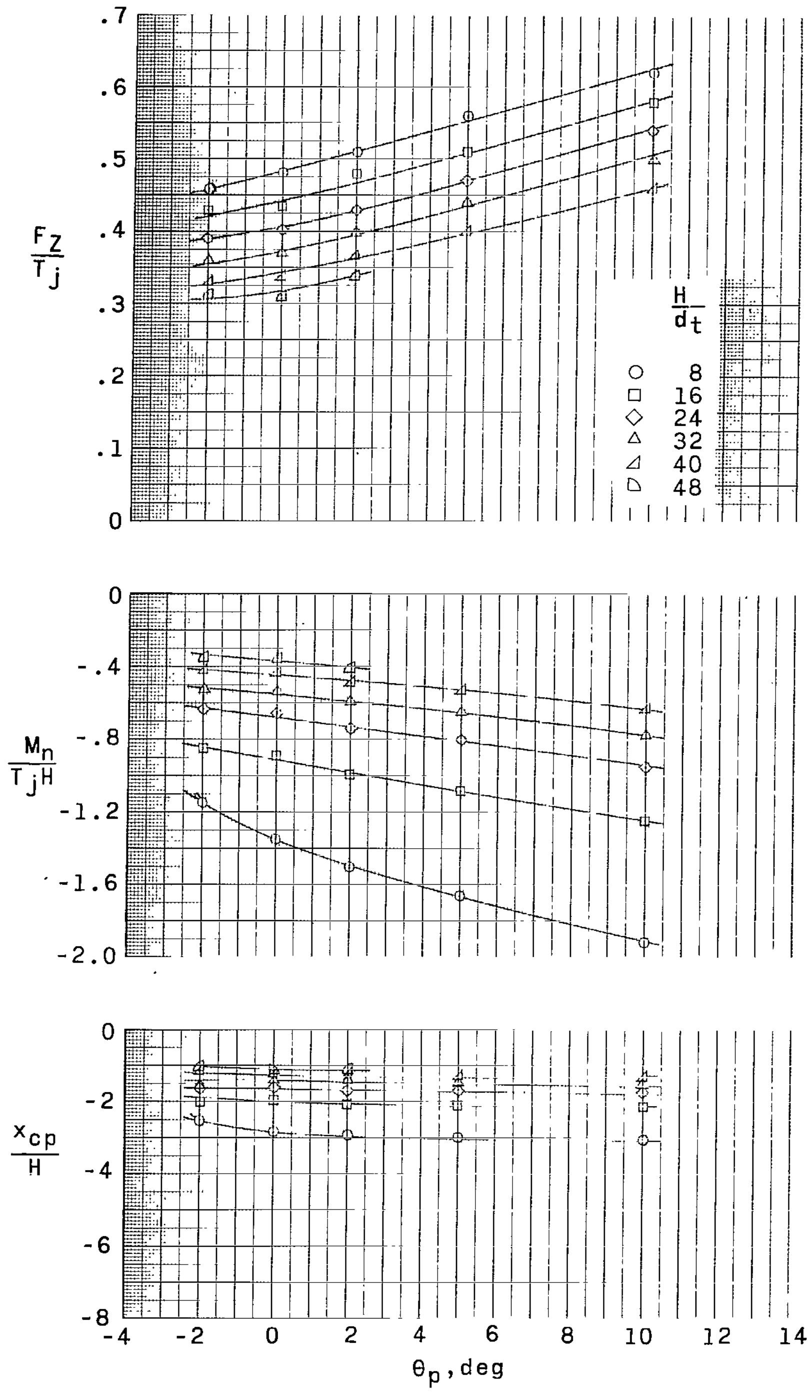
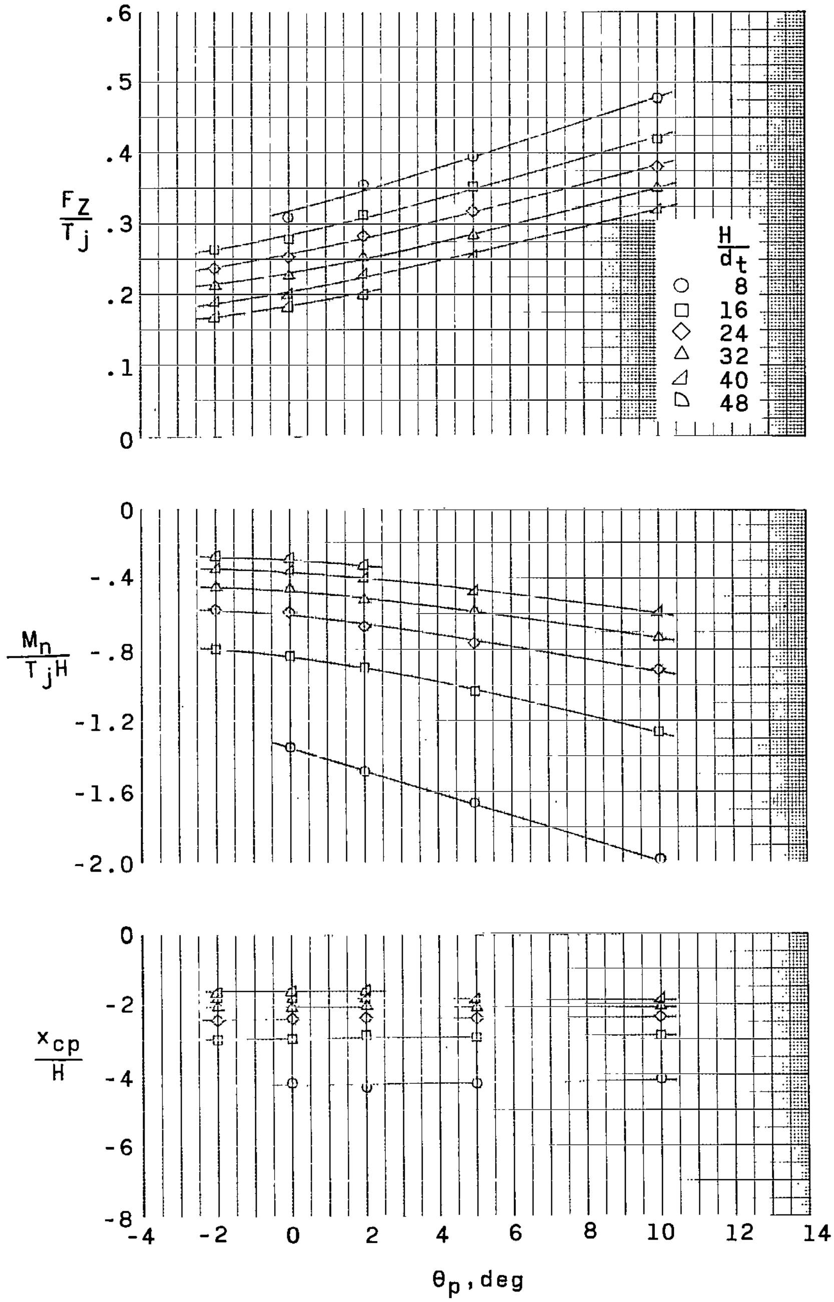


Figure 9.- Variations of normal-force, moment, and center-of-pressure parameters at constant vertical displacement with maximum obtainable jet flow turning angle at $\Delta L_j/L = 0.75$. Air.



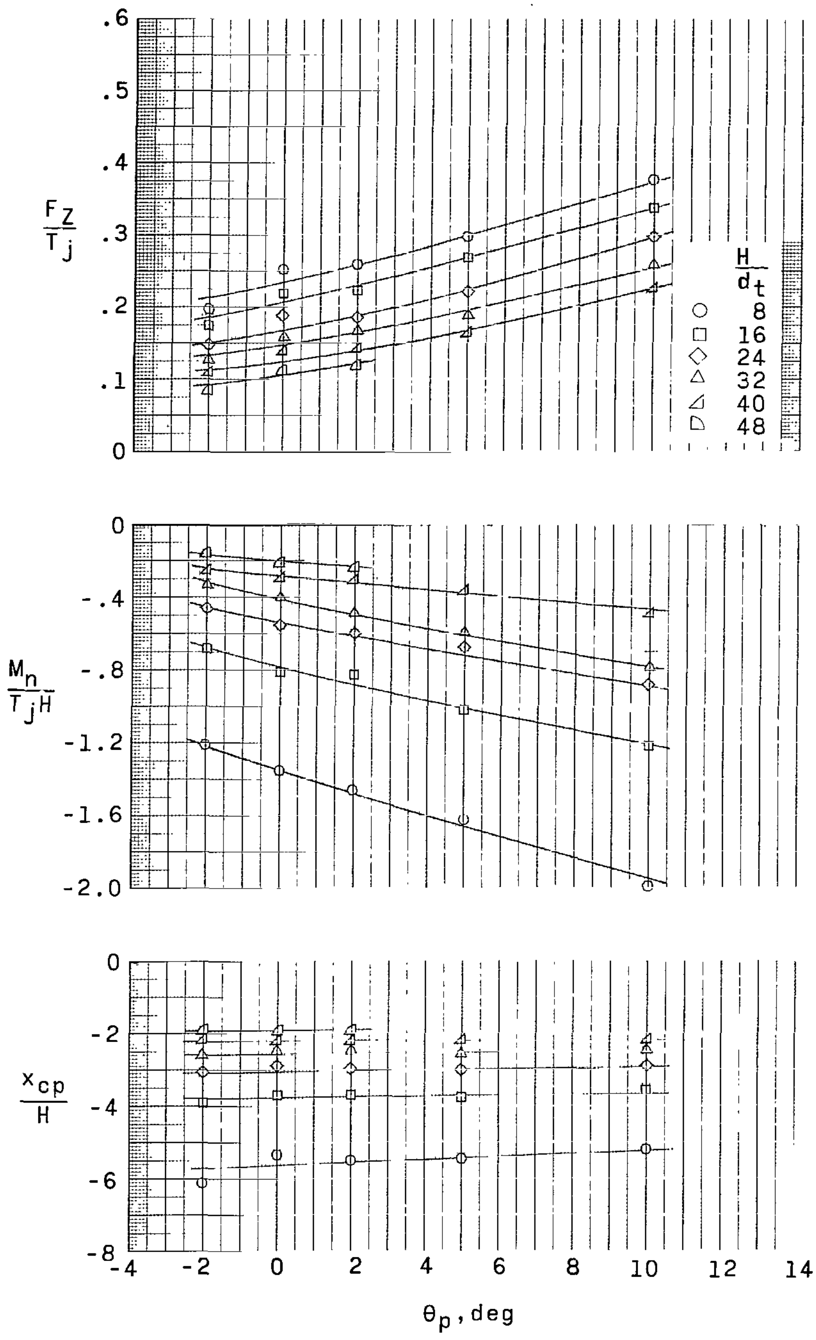
(a) Mach number 1.0 nozzle; air.

Figure 10.- Variations of normal-force, moment, and center-of-pressure parameters at constant vertical displacement for several air nozzles with plate incidence angle at $\Delta L/L = 0.75$.



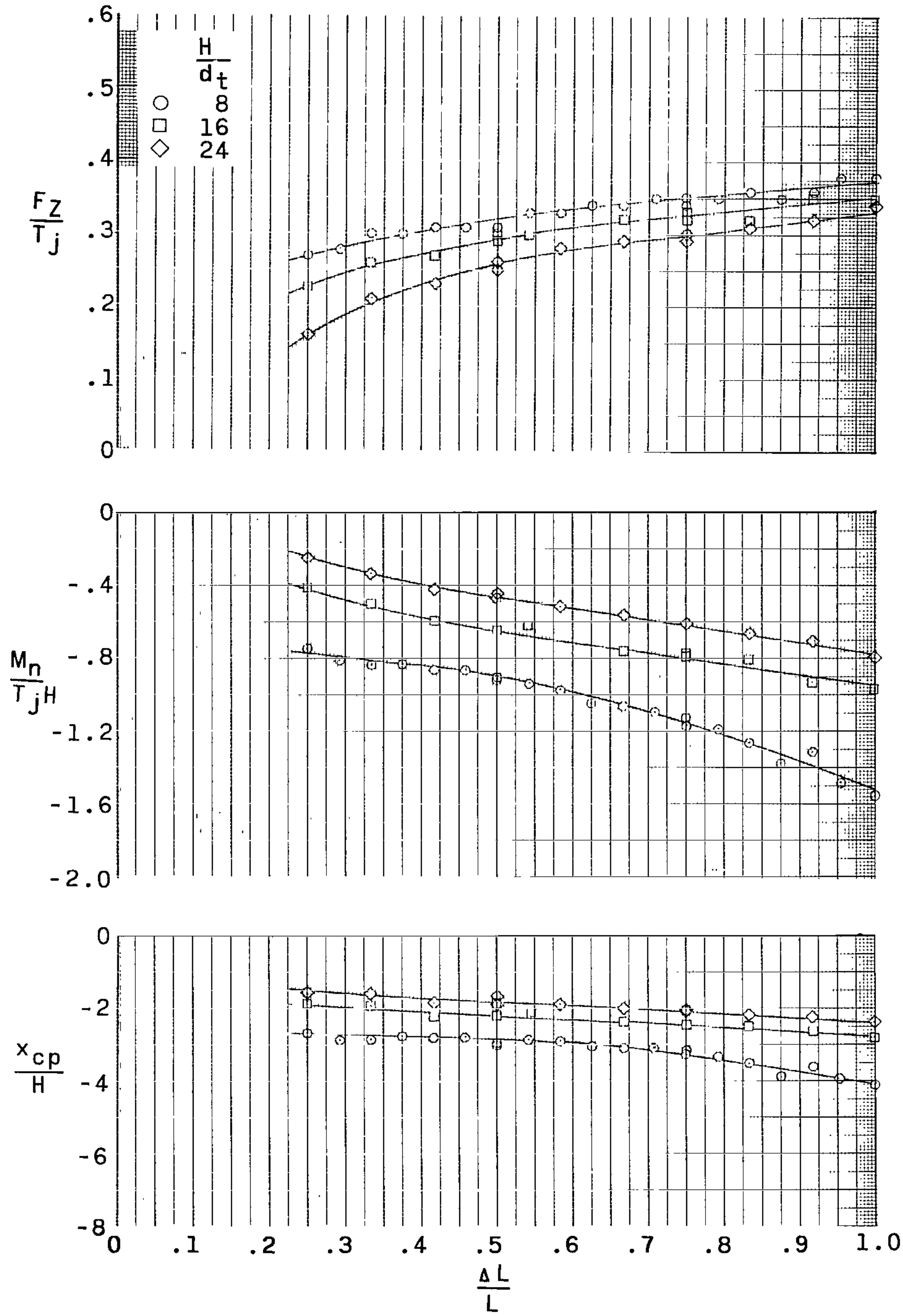
(b) Mach number 3.0 nozzle; air.

Figure 10.- Continued.



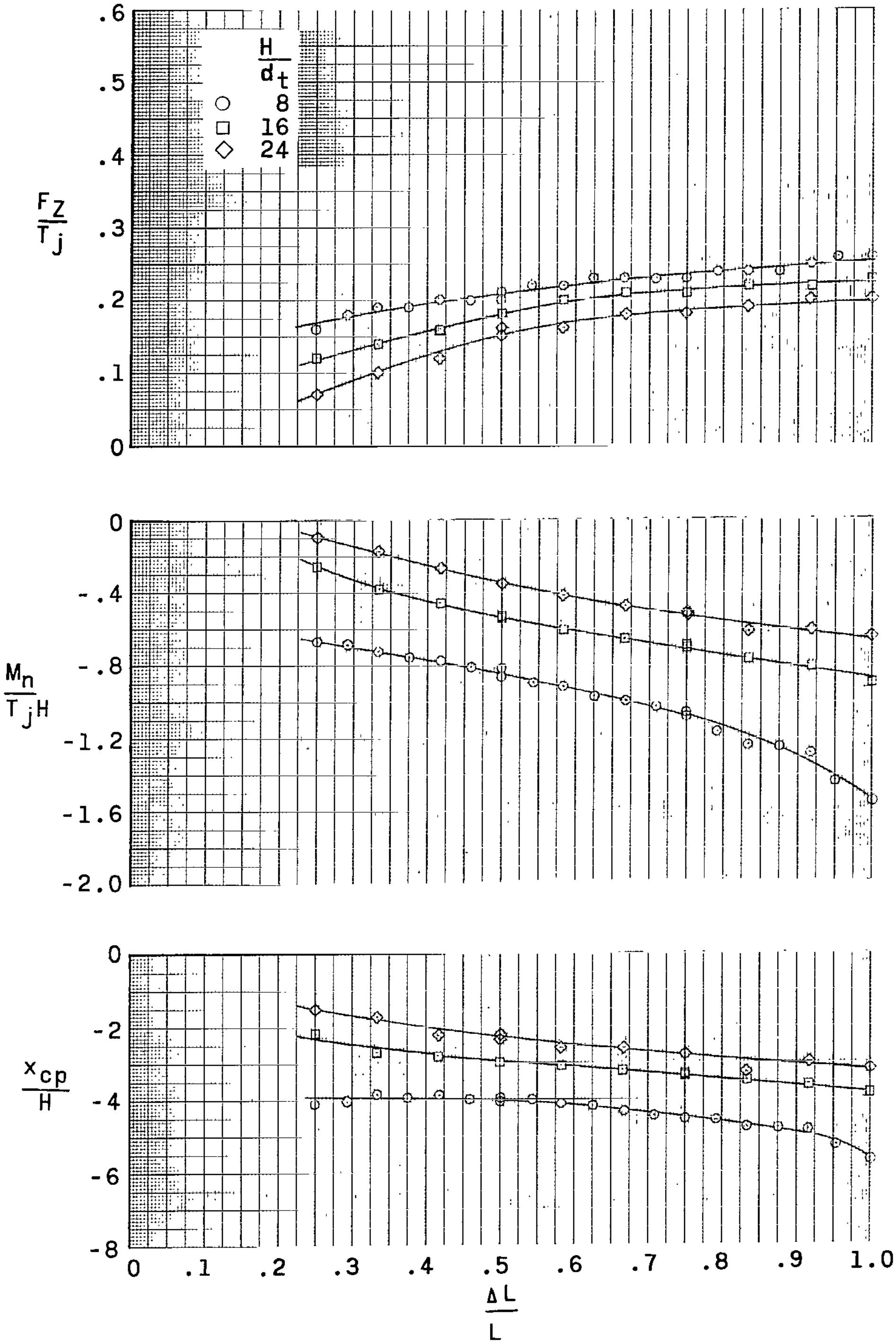
(c) Mach number 5.0 nozzle; air.

Figure 10.- Concluded.



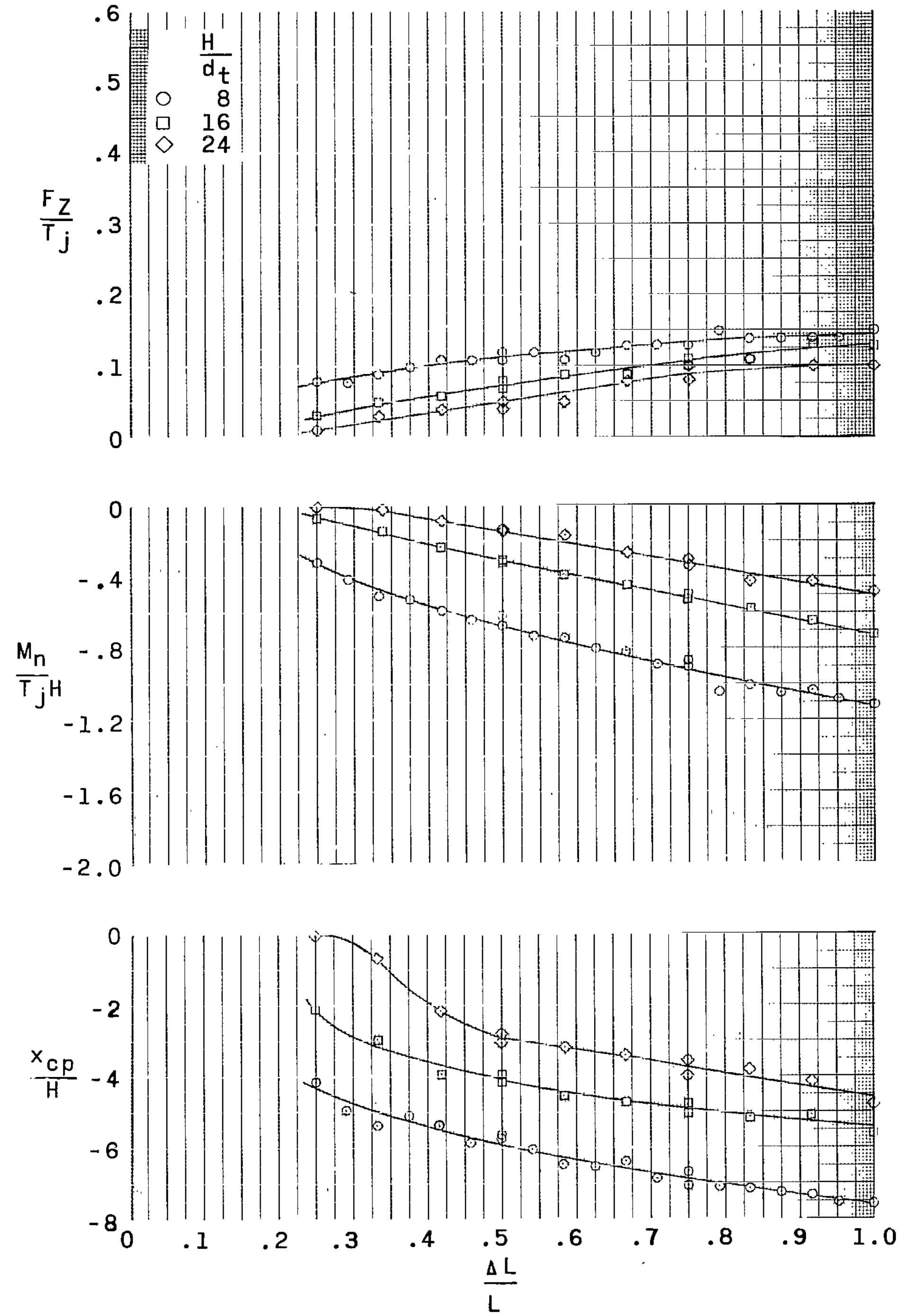
(a) Mach number 1.0 nozzle; helium.

Figure 11.- Variations of normal-force, moment, and center-of-pressure parameters at several vertical displacements of the helium nozzles with longitudinal positions.



(b) Mach number 3.0 nozzle; helium.

Figure 11.- Continued.



(c) Mach number 7.0 nozzle; helium.

Figure 11.- Concluded.

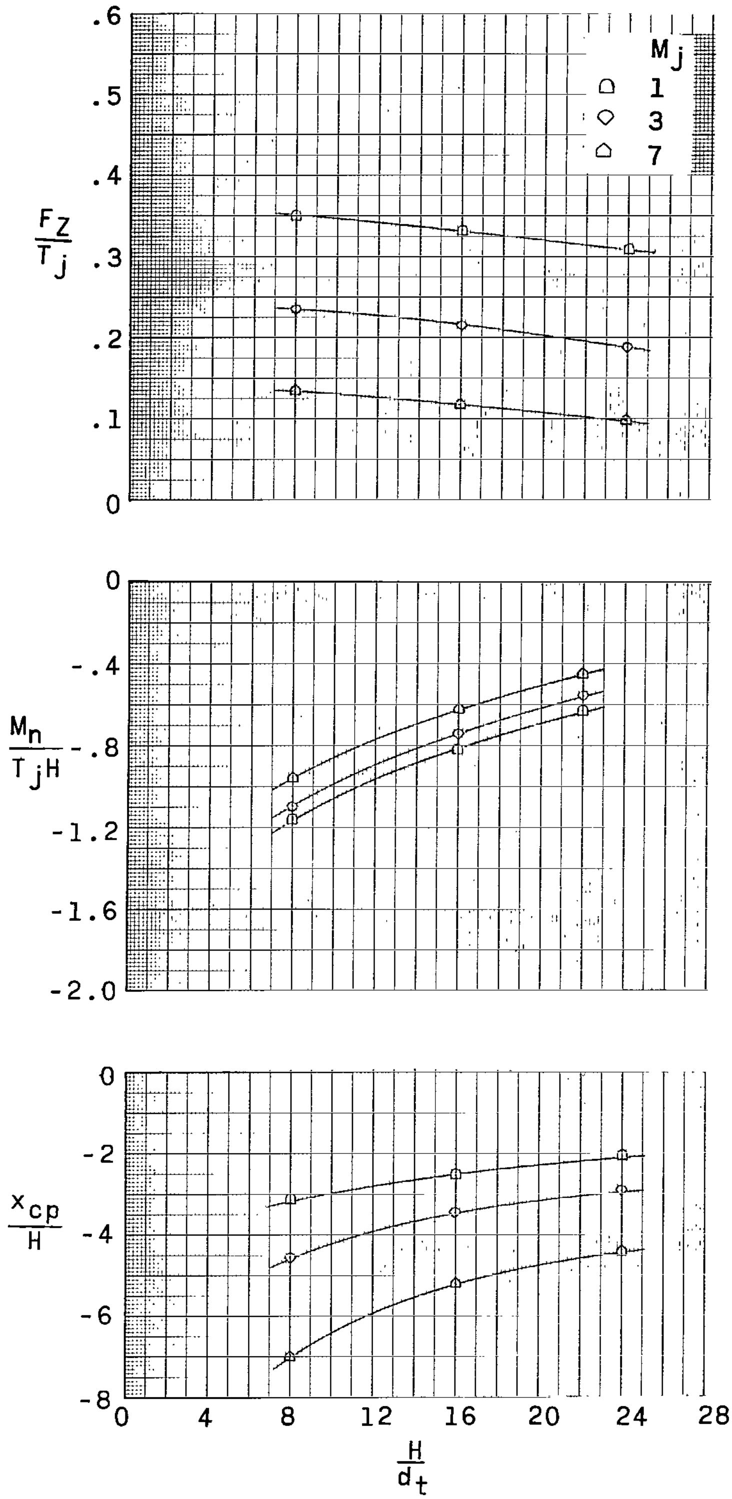
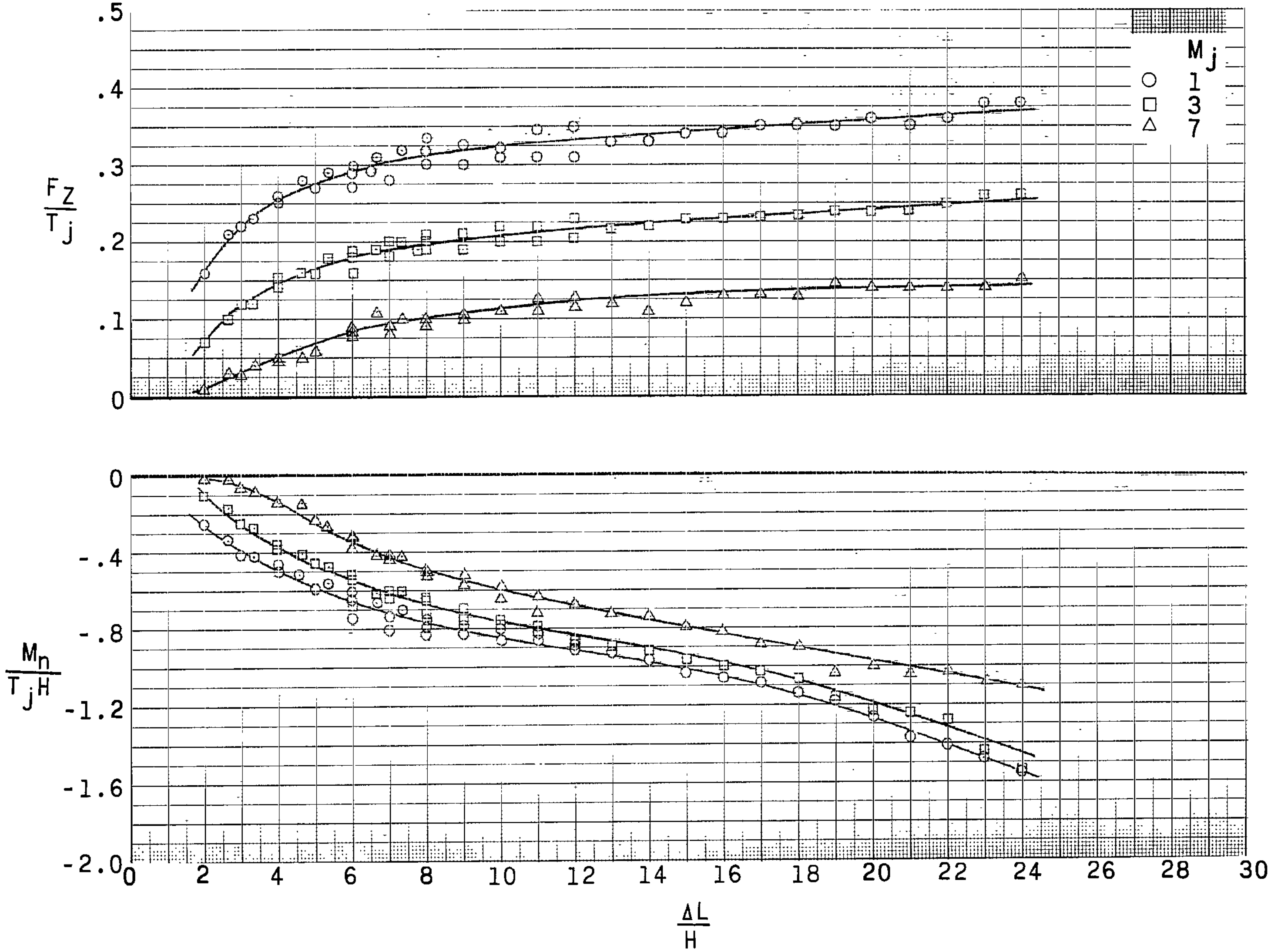
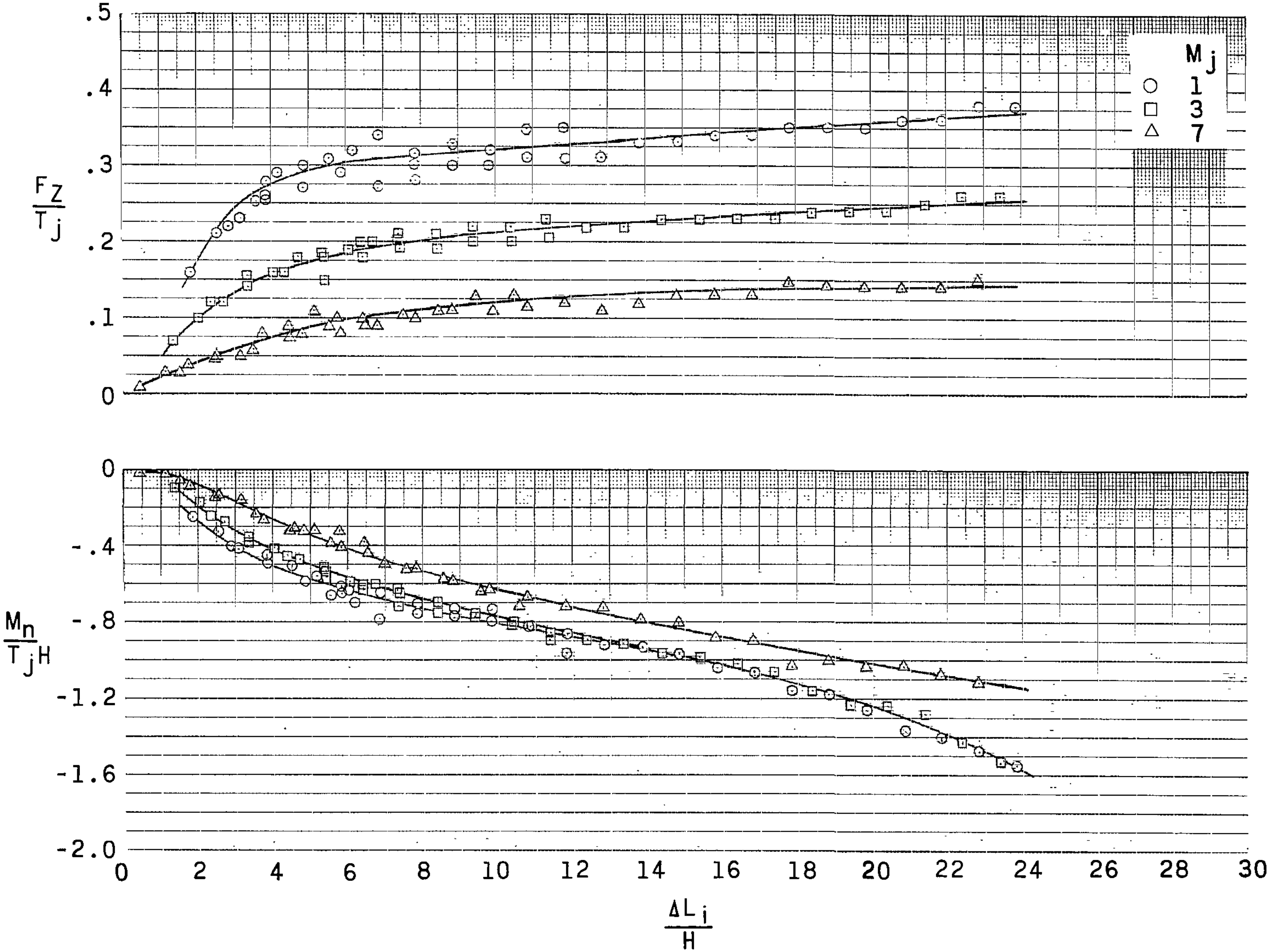


Figure 12.- Variations of normal-force, moment, and center-of-pressure parameters for the helium nozzles with vertical position at $\Delta L_j/L = 0.75$.



(a) Positions normal to plate; helium.

Figure 13.- Variations of normal-force and moment parameters for the helium nozzles with ratio of longitudinal position to vertical displacement.



(b) Positions at nominal jet-impingement points; helium.

Figure 13.- Concluded.

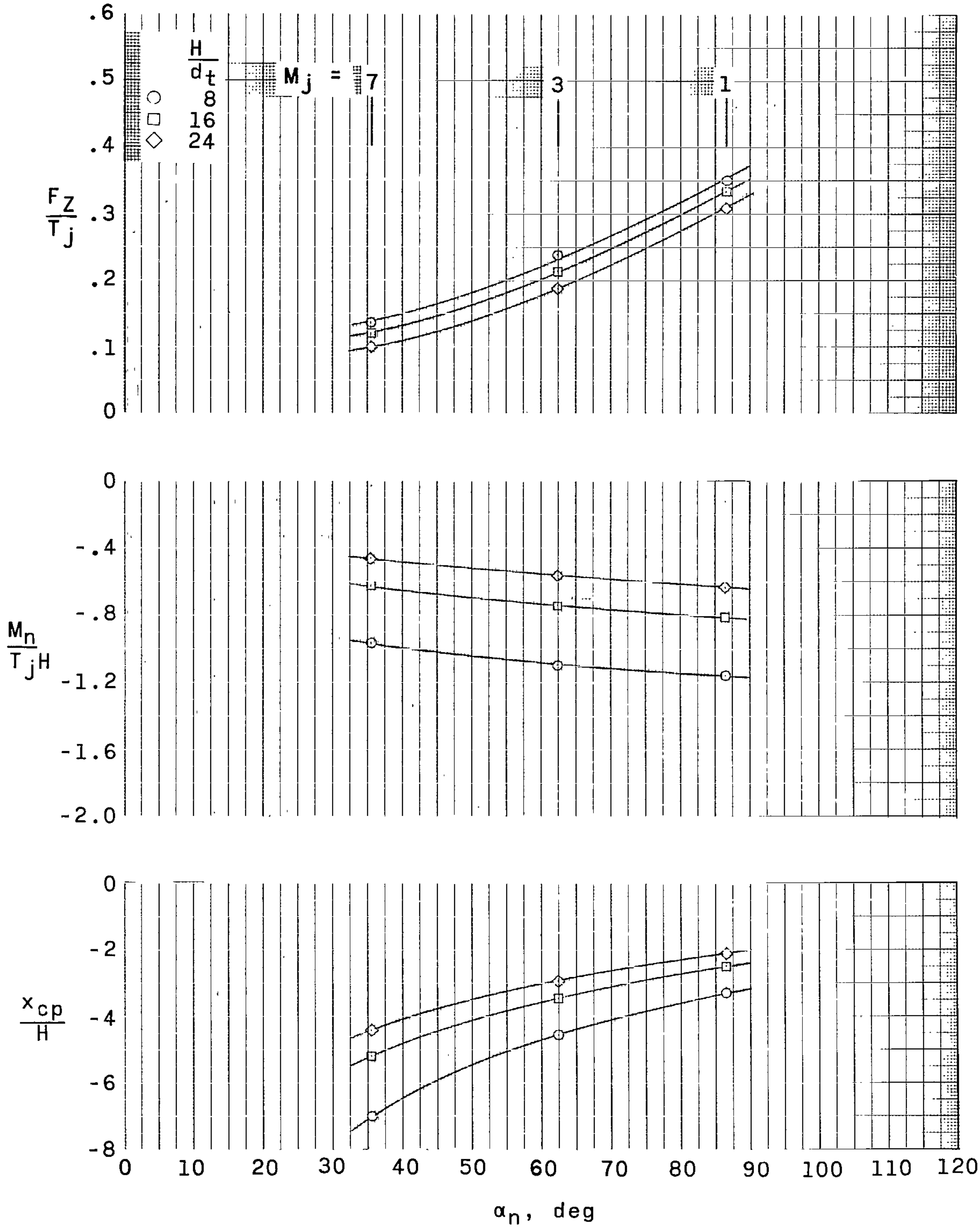


Figure 14.- Variations of normal-force, moment, and center-of-pressure parameters at constant vertical displacement with initial jet flow turning angle at $\Delta L_i/L = 0.75$. Helium.

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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